TECHNICAL REPORT: CONSIDERING LAND USE AND PRICING IN METROPOLITAN TRANSPORTATION PLANNING

NOVEMBER 1989

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PREFACE

The 1990 Clean Air Act Amendments (CAAA) and the Intermodal Surface Transportation Efficiency Act (ISTEA) both require greater consideration of land use in the development of transportation plans and programs. In addition, ISTEA emphasizes consideration of socio-economic factors and efficiency objectives in the development of transportation plans and programs, and encourages urban areas to move towards congestion pricing solutions. Many urban areas will seek to evaluate social costs of transportation, and may become interested in congestion pricing as a solution to both congestion as well as air quality problems.

The attached Metropolitan Planning Division Technical Report, entitled, "Considering Land Use and Pricing in Metropolitan Transportation Planning" incorporates recently completed FHWA research that could help State and local transportation planners understand better the implications of land use and pricing strategies, and provides examples of how these strategies may be considered in the planing process.

This research document is provided solely to share knowledge that has been gained from FHWA research, and does not suggest that States or MPOs are in any way required to undertake the types analyses included herein.

The report is a compilation of four papers as follows:

1. Genevieve Giuliano's paper reports findings on the relationships between urban form, transportation supply, and efficiency of the transportation system. It is entitled, "Relationships Between Urban Form and Transportation: Implications for Long Range Planning."

2. Patrick DeCorla-Souza's review of MPO simulation studies seeks to assess the potential contribution of development patterns to the moderation of highway travel demand and traffic congestion. It is entitled, "The Impacts of Alternative Urban Development Patterns on Highway System Performance."

3. Mark Hanson's review of the societal costs of highways is entitled "Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use."

4. Anthony R. Kane's and Patrick DeCorla-Souza's case study demonstrates the type of information planners will need to "sell" a congestion pricing strategy. It is entitled, "Region-wide Toll Pricing: Impacts on Urban Mobility, Environment and Transportation Financing."

Any questions on the above research may be directed to Patrick DeCorla-Souza at (202) 366-4076.

ABSTRACT

This report incorporates recently completed FHWA research that could help State and local transportation planners understand better the implications of land use and pricing strategies, and provides examples of how these strategies may be considered in the planing process. This research document is provided solely to share knowledge that has been gained from FHWA research, and does not suggest that States or MPOs are in any way required to undertake the types of analyses included herein.

Giuliano's "Relationships Between Urban Form and Transportation: Implications for Long Range Planning" reports findings on the relationships between urban form, transportation supply, and efficiency of the transportation system. DeCorla-Souza's "The Impacts of Alternative Urban Development Patterns on Highway System Performance" reviews MPO simulation studies and seeks to assess the potential contribution of development patterns to the moderation of highway travel demand and traffic congestion. Hanson's "Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use" reviews the societal costs of highways. Kane's and DeCorla-Souza's "Region-wide Toll Pricing: Impacts on Urban Mobility, Environment and Transportation Financing" is a case study demonstrating the type of information planners will need to "sell" a congestion pricing strategy.

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Relationships Between Urban Form And Transportation: Implications For Long Range Planning

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Contents

1. Introduction

This report presents research findings regarding the relationships between urban form, transportation supply, and system efficiency. The research had three objectives: 1) to conduct a review of the literature on transportation and urban form, 2) to identify empirical measures appropriate for analyzing relationships between urban form, transportation, and economic efficiency, and 3) to develop a set of future urban form/ transportation supply options that could promote more efficient urban development patterns. This report focuses on Tasks 2 and 3.

The research presented in this Report is part of a research program that will provide support for future transportation planning. The results will be used to develop and evaluate possible transportation policy alternatives.

The remainder of this Report is organized in four sections. Section 2 presents a brief summary of the literature on transportation/urban form relationships. Section 3 discusses measures that can be used to analyze these relationships. Section 4 discusses issues related to using transportation policy to achieve a more efficient land use/transportation system, and the last section offers some policy alternatives for doing so that could be evaluated at the sketch planning level.

2. SUMMARY OF LITERATURE

Interest in the relationship between transportation and urban form among researchers in many disciplines has resulted in an extensive body of both theoretical and empirical literature.

2.1 Theory

The theoretical literature seeks to explain or describe the relationship between transportation and urban form. This relationship is based on the assumption that access has value, and the value of access is reflected in the value of land, which in turn determines the distribution of activities within the metropolitan area.

Land use theory does not imply that there is any ideal urban form. Rather, theory predicts the optimal urban form under certain conditions and assumptions. In this context, deliberation as to whether alternative urban forms (say monocentric versus polycentric) are "better" or "more efficient" are irrelevant. Efficiency can only be determined by relative costs, available resources, etc. It is therefore not surprising that the optimal solutions that emerge from these theories and models may be extremely diverse. For example, it is possible to show that a highly concentrated urban form is optimal under some conditions, while a dispersed form may be optimal under other conditions (e.g. Mills, 1972; Stone, 1973). From a transportation planning perspective, the conclusion to be drawn is that efforts to move toward a more efficient urban form/transportation system combination depend upon existing conditions: the current activity distribution, the current transportation system, and the resources and mechanisms available to make adjustments in these systems.

2.2 Empirical Findings

There are many attributes or descriptors that might be used to define urban form and its relationship to transportation. These include density or concentration, the distributions of population and employment relative to one another, the existence of single or multiple dominant centers of economic activity, and the range of differences in activity distributions within the metropolitan area. These attributes have been employed in several empirical studies that examine the relationship between transportation and urban form.

2.2.1 Population density

Population density is the single most frequently used indicator of urban form. Traditional urban economic theory posits household location as a function of job access, housing costs, and the cost of all other goods and services. It is assumed that all employment is located at the center of the city. Under these conditions, households compete for locations as close as possible to the city center, generating a declining land rent gradient that is reflected in a corresponding declining population density gradient.

The population density distribution has been used to measure historical changes in urban form (Griffith, 1981; Guest, 1975, Greene, 1980), to compare the relative concentration (or extent of decentralization) between different urban areas (Clark, 1951; Mahmassani, Hadi-Baaj, and Chung Tong, 1988), and to test for the existence of monocentric urban form (Odland, 1978; Gordon, Richardson and Wong, 1986; Getis, 1983). Research results indicate a consistent trend of population decentralization: declining densities throughout urban areas as well as a flattening of the density gradient. Results also suggest the emergence of subcenters, or localized peaks in the density distribution.

Extensive research has been conducted on relationships between population density and various aspects of transportation system efficiency and travel behavior (Hanson and Schwab, 1987; Wilbur Smith and Associates, 1961; Pushkarev, Zupan and Cumella, 1982). High density environments imply spatially concentrated origins and destinations, or high accessibility. High density environments are associated with traffic congestion, lower travel speeds, and shorter trips. Under these conditions, transit, walking and bicycle trips are more frequent. Transit that operates on its own right of way is a particularly attractive option. Higher densities have been associated with high levels of transit demand and therefore with more effective transit service. Rail transit in particular requires high densities for cost effective service. Declining urban densities have been associated with decreases in transit use, as dispersed origins and destinations cannot be effectively served with conventional transit service (Kain, 1988).

Low density environments imply spatially dispersed origins and destinations. These environments are associated with longer trips, higher travel speeds, less congestion, and reliance on the private auto. Individualized transportation is the most cost effective option in low density environments. On a per capita basis, low densities imply more vehicular travel, more fuel consumption, and more air pollution (Newman and Kenworthy, 1988).

While the transportation implications of the two extreme possibilities is straightforward, this is not the case for medium density environments. Medium density environments are in fact the source of some of our most serious congestion problems. Reliance on the auto is extensive, road capacity is limited, and conventional transit service is not effective. This suggests that there is a range of densities for which conventional transportation options are not efficient.

2.2.2 Monocentric versus polycentric urban form

The issue of whether urban areas are best described as monocentric or polycentric has also been the subject of much research. As stated above, recent research indicates that large urban areas are polycentric. Polycentricity is a theoretically logical urban form outcome as agglomeration economies are offset by increasing congestion in large urban areas.

Simulation research indicates that polycentric urban form is more efficient than monocentric form from a passenger transportation standpoint, because total journey to work travel is minimized (Sharpe, 1982; Schneider et al, 1983). Whether or not total transport is minimized depends on the assumptions regarding goods transport (for example, whether all goods must be transported to the city center for export). It is easily seen that if only the journey to work is considered, the more that employment is

decentralized, the less work related travel will be required. The extreme outcome is totally dispersed employment, which in essence represents all workers that work at home.
Simulation research also suggests that transit service is viable in polycentric cities, with traditional fixed route service operating between centers and some form of para-transit service operating within centers (Schneider, 1981). However, recent efforts to provide such services have not been successful; transit usage is limited and thus very costly to provide.

2.2.3 Urban form and the journey to work

The transportation efficiency of polycentric urban form is based on the idea that a decentralized pattern of population and jobs leads to shorter work trips. However, recent research on this subject is mixed. The longest work trips are associated with downtown employment and the largest urban areas (Gordon, Kumar and Richardson, 1987). On the other hand, while work trips that originate and remain in suburban locations are shortest, they are increasing over time (Pisarsky, 1987). Other research indicates that mismatches between job and housing characteristics, exclusionary zoning practices and changing demographics may cause longer suburban commutes (Cervero, 1989). Finally, there is some question as to whether locating as close as possible to work is a primary objective for most households (Hamilton, 1982; Clark and Burt, 1980).

Summarizing this research suggests that decentralized urban forms may result in shorter work trips, but other factors may play a role as well. These include various forms of job/housing imbalances, as well as household location preferences beyond job access considerations. These results are an important consideration for planning efforts directed at improving the match between transportation and urban form, for they suggest that actual travel outcomes associated with specific transportation/urban form characteristics are difficult to predict.

3. EMPIRICAL MEASURES

Research on relationships between transportation and urban form have been limited by data availability. In general, population and employment data are far more accessible than transportation system performance data.

3.1 Data Resources

The most readily available data source is that of the U.S. Census. Population characteristics, housing characteristics, and employment information can be obtained at varying levels of aggregation, from SMSA down to census tracts. Until 1980, employment data was reported only by place of residence. Employment data by both place of residence and place of work were collected in the 1980 census, thus providing journey to work flows at the census tract level.

A second major source of travel data is the Nationwide Personal Transportation Study, collected in 1969, 1977 and 1983 for the U.S. DOT. The NPTS data provide information on all aspects of travel behavior, but the data are aggregated by metropolitan size category and cannot be desegregated to specific areas. In addition, because of sampling differences between the surveys, their comparability is limited.

Transportation system performance data are less extensive. Traffic volume counts are sampled as part of the Highway Performance Monitoring System reporting requirements. These provide only limited information on traffic flow at the metropolitan network level. Additional flow data are collected via sample screenline counts, and areas that have coordinated traffic signal systems usually have intersection flow data. Transit service data are readily available due to the extensive reporting requirements public transit agencies must meet.

Data on travel flows are the most difficult and costly to obtain. Travel behavior data beyond that provided in the census must be acquired through special surveys. Due to financial constraints, most regions do not have up-to-date travel behavior data. For example, the most recent travel survey data available for Southern California were collected in 1976. Plans to conduct another survey have been delayed due to funding limitations.

3.2 Measures

The literature revealed a wide variety of measures used in empirical studies of transportation-urban form relationships. They can be roughly divided into three groups; measures of urban form, transportation supply, and transportation demand.

Urban form measures are based on the distribution of activities, e.g. population and employment. These distributions can be used to develop measures of concentration (e.g. degree of compactness) and of spatial distribution (for example monocentric vs polycentric).[2] They can also be used to develop more descriptive measures of overall form (e.g. square, circular, axial), or of internal structure (sectoral, concentric zone, multiple centers). Indirect measures of urban form are also sometimes used. Some examples are city age, decade of most rapid growth, and modal orientation.

Transportation supply measures are of two types: those that describe network characteristics, and those that express quantities of transportation system components (Table 1). Network characteristics include geometric form, mode, and extent or intensity. Measures of transportation system components include quantities of transit services provided, freeways, arterials and other types of facilities provided. There are also measures of transportation system performance. These reflect the outcomes of supply and demand on the system, and thus are "mixed" measures. Some examples are also included in Table 1.

Table 1: Transportation Supply Measures

Network Characteristics	**Examples**
Form	Grid, Radial, Circular

Geometry	Square, star, rectangle
Mode	Auto, Bus, Rail
Intensity	Lanes-Miles/ Area, Transit Vehicles/Population
System Components:	**System Performance:**
Miles of roadway by type, total cost, transit route-miles	Freeway and arterial level of service, intersection capacity utilization

Transportation demand measures are more numerous (Table 2). They can be divided into two categories: aggregate measures and disaggregate measures. Aggregate measures include both indicators of total demand (for example VMT, gasoline consumption, transit passenger-miles) as well as rates (for example VMT/population, transit trips/population). Disaggregate measures focus on individual or household travel demand. These include trip characteristics (time of day, mode, cost, length), amount of travel (trips per day, VMT per day), and measures of travel propensity.

Table 2: Transportation Demand Measures
Aggregate:
Total Demand: Vehicle Miles Traveled, gasoline consumption, vehicle trips, person trips, transit passenger miles
Average Rates: VMT/population, Average Daily Travel, vehicle trips/population, transit trips/population
Disaggregate:
Trip Characteristics: travel time and distance, mode, time of day, cost
Quantity of travel: trips per person per day, VMT per person, household person-trip rate
Travel propensity: auto ownership, household income, employment, household demographics

Choice of measures of course depends upon the specific purpose of the research. Table 3 gives some examples of measures used in empirical studies, together with information on the purpose and results of the study. The examples cover a wide range of topics, and illustrate the types of measures that are appropriate for specific research issues. More detailed descriptions of each of the studies are presented in the Appendix.

4. USING TRANSPORTATION POLICY TO DEVELOP A MORE EFFICIENT SYSTEM

A major purpose of this research is to develop planning alternatives that could lead to a more efficient transportation-land use pattern. It is therefore appropriate to consider the types of planning strategies that might be most effective, and to identify conditions under which such strategies are likely to be most successful.

4.1 Transportation - Urban Form Relationships and Transportation Policy

The literature review revealed that extensive research exists on the relationship between transportation and urban form. For any given existing development pattern, it would be relatively straightforward in theory to identify changes in the transportation system that could improve system efficiency. For example, shifts of peak period trips from driving alone to more productive modes such as carpooling or transit would reduce congestion and improve transportation efficiency. The problem, however, is how to accomplish such a shift. Efforts to attract new transit riders by investing in major new facilities or maintaining low fares have been largely unsuccessful (Kain, 1988; Meyer and Gomez-lbanez, 1981; Fielding, 1983). Similarly, efforts to increase carpooling by providing carpool matching services, various carpool subsidies, or high occupancy vehicle lanes have had only limited success (Giuliano, Levine and Teal, 1989; Teal, 1987). Thus the key issue is not the identification of more efficient transportation - urban form combinations, but rather the identification of policies that could lead to these more efficient outcomes.

4.2 Changes in the Transportation - Urban Form Relationship

It is also important to consider the changes that have taken place in the distribution of activities and the implications these changes have for transportation policy. Foremost among these changes is the decentralization of both population and employment.

4.2.1 Decentralization

Decentralization has always resulted from improvements in the transportation system, but the dominance of the automobile and highway system has resulted in such extensive shifts that the fundamental pattern of urban land use has changed (Muller, 1981; Jackson, 1985). This trend is not unique to the United States, nor can it be attributed entirely to public policy decisions. Decentralization has occurred even in countries where government has controlled auto ownership, extensively subsidized mass transit, and controlled land use in an effort to retain strong urban centers and higher density development patterns (Getis, 1983; Kain, 1985; Lowry, 1988). Furthermore, forecasts of future trends are unanimous in their prediction of continued decentralization and reliance on the automobile, and these trends are seen as world-wide (Shortreed, May and Dust, 1985; Webster and Bly, 1987).

Table 3: Examples of Measures Used in Empirical Studies

Author	Purpose	Measure	Findings
Cervero, 1988	Determine impact of relative distributions of population and employment on journey to work and congestion	origin destination work trip data, zonal population and employment trip characteristics, freeway LOS	mismatches between occupational characteristics and local housing stock associated with longer work trips and traffic congestion
Edwards and Schofer, 1976	Analyze relationship between energy consumption and urban form	Population and employment characteristics, generalized travel costs, travel trip characteristics	Energy consumption significantly related to urban structure characteristics and auto use
Gordon, Richardson and Wong, 1986	Analyze relationship between urban structure and travel	Population density distribution employment density, work trip length	Urban structure best described as polycentric; work trip shorter in suburban areas
Hanson and Schwab, 1987	Analyze relationship between accessibility and intraurban travel behaviour	Density of activity location with respect to household location, travel characteristics	Accessibility has weak positive association with travel characteristics
Kain and Fauth, 1977	Analyze relationship between mode choice and auto access, urban structure characteristics	Work trip characteristics, housing characteristics and location, transit and highway supply characteristics	Mode choice and auto ownership significantly urban structure and modal supply
Newman and Kenworthy, 1988	Analyze relationship between gasoline consumption and urban form	Location with respect to CBD, trip characteristics fuel consumption	Locational factors have a greater impact on fuel consumption than congestion
Payne-Maxie Consultants, 1980	Determine land use and development impacts of beltways	Population and employment characteristics, measures of economic growth	More consistent relationship between beltways and land use change
Pushkarev Zupan and Cumella, 1982	Determine conditions for cost effective rail mass transit	Population and employment density, aggregate travel characteristics, transit service and cost characteristics	Rail transit most effective with concentrated employment center and high population density

Decentralization has weakened the importance of transportation cost and accessibility in location choice. These factors are no longer as important as they were when the transportation system was limited (as in the streetcar era), when transport costs represented a significant portion of goods production costs, or when economic activity was concentrated in the center of the city. In a decentralized urban environment, transport cost is just one among many factors that influence the location choices of households and firms.

Other changes in the urban environment also merit discussion. These include changes in the structure of economic activity, the scale of development, and the influence of local governments in land use decision-making.

4.2.2 Structure of Economic Activity

The relative importance of transport cost in economic activities has declined as the transportation of information has been substituted for the transportation of goods in the shift to a predominantly service-oriented economy. In addition, the market orientation of firms is increasingly national or international in scope, making access to the national transport network (airports, the interstate highway system, and the rail system) relatively more important than access within the metropolitan area itself (Shortreed, May and Dust, 1985).

Agglomeration economies are also important. Agglomeration economies are the scale economies realized by individual firms from locating near "like" or "complimentary" firms (for example, software developers locating near computer manufacturers). Agglomeration economies are associated particularly with the service sector, and thus can be expected to continue to be important in firm location choices. Thus the location choices of firms that generate strong agglomeraton economies are likely to have a significant influence on urban form.

4.2.3 Development Scale

The scale of development has increased over the past thirty years. The residential development industry is increasingly dominated by major projects. Planned communities, involving large land parcels and developing over several years, have become the norm. Similarly, industrial and commercial projects now typically involve master planned industrial parks, office centers, or mixed use developments. This trend has been reinforced in recent years by the increasing reliance on developer contributions to fund infrastructure needs, as large developers are more likely to be able to incur the large financial risk involved. These changes have had two important consequences: the availability of large tracts of land is a critical factor (and most vacant land is at the periphery of metropolitan areas), and land use changes are determined by fewer decisions. Thus unique local conditions are becoming more important determinants of changes in urban form.

4.2.4 Influence of Local Governments

Local governments have a potentially strong role in land use decisions through their zoning authority. Zoning has historically played a limited role, serving primarily to separate uncomplimentary land uses (i.e. residential areas and noxious facilities) and to enforce basic construction and infrastructure requirements. More recently, however, local governments have expanded their land use regulatory activities. Given the scale of most new developments, local government approval and compliance with a specified environmental review process is usually a necessity. In addition, the lack of traditional public funding sources for infrastructure requirements of new development has resulted in the implementation of a variety of local financing mechanisms to collect needed revenues from the new development itself.

If strong community preferences are present, as for example are illustrated by the grass roots growth control movements active in many urban areas today, local jurisdictions can use zoning power to prevent or downgrade development despite favorable market conditions. They can also promote development through tax breaks, infrastructure provision, financial assistance and other incentives. For example, such strategies have been used extensively in downtown redevelopment efforts.

4.2.5 Summary

Decentralization, changes in the structure of economic activity, large scale development and increased influence of local jurisdictions in land use decision-making have all contributed to creating a very different set of circumstances for transportation policy. These changes make it far more difficult to develop "efficient" transportation plans or to identify urban form alternatives that could be associated with specific travel patterns. They also make prediction of the travel impacts of future policy alternatives more uncertain, as local circumstances play an increasingly important role.

On the other hand, the changes discussed here also suggest the conditions under which the link between transportation and land use may be the strongest: when transport costs are significant, or when transport or development decisions significantly affect accessibility. These conditions are best met in two very different circumstances: heavily congested downtown areas and rapidly growing suburban areas. Planning alternatives based on these concepts will be discussed in the following section.

5. PLANNING ALTERNATIVES

Before discussing some possible planning alternatives, it is appropriate to review the analytical tools required to properly evaluate them, and to discuss strategies for developing appropriate alternatives.

5.1 Research Methodology

The purpose of this research is to propose planning alternatives that would lead to more efficient urban patterns from the transportation point of view, or that would lead to a better match between urban form and transportation. In order to evaluate these alternatives, the interaction between land use and transportation must be considered. If, for example, one alternative calls for construction of new highways in outlying areas, then the impact of these facilities on the location of future housing and employment must be analyzed. Similarly, a policy to implement market pricing in the central city will affect the relative cost of driving compared to other modes, and thus affect mode choice. It will also affect location choice decisions by making non-central city locations relatively more attractive. This type of analysis consequently requires that some type of land use model be incorporated in the transportation modeling system. If the conventional (UTP) forecasting approach is taken, where no feedback between transportation and land use is considered, evaluation results are likely to be incorrect and misleading.

This research also requires that policies that may affect travel demand be fully analyzed. Any policy that significantly changes mode split will have a corresponding influence on the level of service of each mode, which in turn will affect mode choice. Again, these mutual effects must be taken into account in order to accurately evaluate policy alternatives.

These requirements imply a more complicated modeling approach than is generally utilized in transportation planning and forecasting. Differences are illustrated in Figure 1. The shaded portion and black arrows represent the UTP modeling system. The lighter lines and boxes outside the shaded area represent the additional linkages necessary to capture feedback effects. Models of this type are available and have been used in regional planning exercises (Putman, 1983).

5.2 Developing Planning Alternatives

The development of planning alternatives is a frequently overlooked element in the transportation planning process, yet the ultimate outcome of any planning exercise clearly depends greatly on the alternatives considered. The most effective alternatives are those which address specific objectives, define the bounds of feasibility, and provide the most information to decision-makers (Giuliano, 1985; Giuliano et al, 1983; Nijkamp,1980). Previous research suggests that at the sketch planning stage, "extreme" alternatives are most effective. These alternatives reflect extreme points of view or objectives, and thus provide the most information on the range of possibilities for alternative plans. By their nature they are unrealistic, and are meant only to stimulate a process for arriving at more suitable compromise alternatives.

This method of alternative generation has been developed from mufti-objective decision models (Nijkamp, 1980; Rietveld,1980; Zeleny, 1982). These models are based on the concept that there is no single, optimal solution for a given problem because of conflicts between objectives and differences in preferences among decision-makers. In the case of transportation planning, for example, environmental objectives are frequently in conflict with cost or service objectives. The multi-objective decision model posits an "ideal solution," a solution that is optimal for all objectives but is not attainable. The evaluation process then seeks to identify the alternatives that are as similar as possible to the ideal. Application of multi-objective decision methods has shown that an effective way to identify these "best possible" or "compromise" alternatives is to begin with a set of extreme alternatives, in which each alternative seeks to achieve a different objective. This approach has been followed in developing the alternatives presented here.

5.3 Planning Alternatives

It was mentioned in Section 4 above that the areas where land use and transportation are likely to be most closely related are heavily congested central cites and rapidly growing suburban areas. Heavily congested central cites typically have no additional right-of-way available for highway expansion, and thus must rely on alternative modes for additional travel capacity. Higher densities also make transit more viable, while high land costs generate the incentive for high development densities. These conditions lend themselves to a number of policy alternatives that could result in a more efficient transportation system. For example, parking pricing, designation of auto-free zones, and arterial high occupancy vehicle lanes would all affect mode split and thus increase the person-capacity of the transportation system. While these policies would also have some decentralizing effect (some workers and employers would move to lower cost locations), it is likely that overall impacts would be positive.

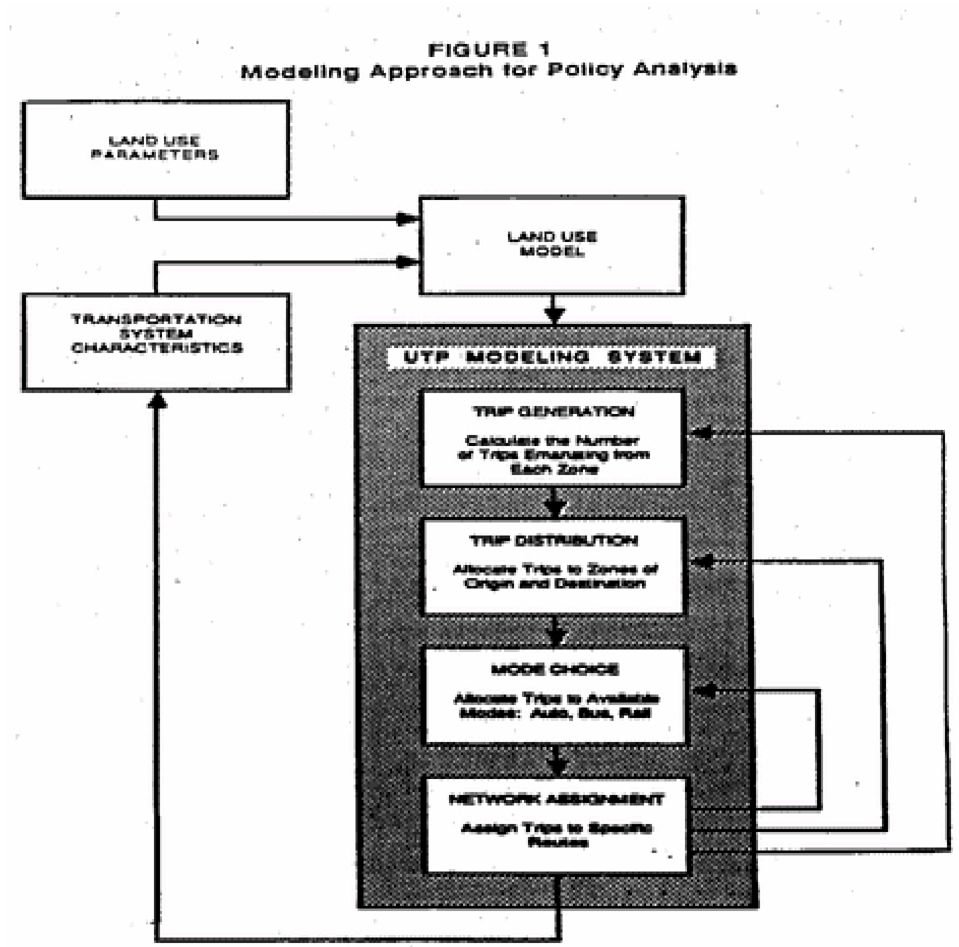

Figure 1: Modeling Approach for Policy Analysis

Rapidly growing suburban areas face a different set of problems. These areas have developed without the benefit of adequate public funding for highway infrastructure, yet they have developed around an automobile-based transportation system. Development patterns and densities are not conducive to other modes. As a result, the available roads are overburdened with traffic.

It is not surprising that these areas have originated creative financing arrangements, such as public-private partnerships, and have revitalized the toll road concept in an effort to expand the highway system and make continued growth possible. The result of these efforts is an unusually close relationship between land use and transportation planning and decision-making. New facilities must pass a market test (because both user fees and private funds are involved) and must be linked with specific development projects (because they are the revenue source). New facilities are also likely to significantly affect accessibility, as they typically are constructed in undeveloped areas. Under these conditions, transportation investment decisions carry with them the opportunity to guide land use patterns so as to maximize system efficiency.

This discussion has focused up to now on current technology. However, given that the ultimate goal of this research is the development of a policy for long range planning, it is also appropriate to consider alternatives based on new technologies that may be considered feasible within a twenty five year time frame. Thus the following scenarios include current as well as possible future technology alternatives. Four basic alternatives are proposed: 1) Pricing Emphasis, 2) Direct Linkage, 3) Land Use Controls, and 4) New Technology.

5.3.1 Pricing Emphasis

Establishing a system of pricing that reflects the true cost of automobile travel is a straightforward way of improving transportation efficiency. Automobile use is currently underpriced, in that its congestion effects and pollution effects are not directly paid for by the auto user. In addition, current gasoline taxes are not sufficient to cover the costs of maintaining and expanding the highway system, and local streets and roads are financed primarily through property taxes, rather than by user charges.

This alternative calls for a system of differential pricing based on VMT and congestion. Peak travel would be priced twice as high as off peak travel on congested facilities (this is simply a gross approximation of peak load pricing; it would also be possible to establish the price level necessary to eliminate congestion for a fixed system). Since pricing is based on VMT, this is equivalent to converting the highway system to a toll road system. This alternative also assumes higher fees for congested areas like downtown and other major employment locations. It is assumed that technology is available to implement such a pricing system.

Parking would be charged at current market rates. This implies charges on the order of $6/day for central city locations, $3/day for suburban employment centers, and $1 to $2 outside employment centers. Parking fees in the CBD could be much higher. All other auto costs would remain constant. Transit fares would remain at current levels, but the amount of service provided would depend upon the change in transit demand resulting from the changes in auto costs. In addition, HOV facilities are assumed to be available on all freeways and selected arterials. This alternative would have its greatest impact on the downtown, and on ever heavily congested areas. It thus takes advantage of the first set of favorable conditions discussed above.

Pricing strategies have historically been infeasible for political reasons, as any policy that increases the cost of using an auto has no constituency. This alternative has the additional difficulty of disproportionately affecting the central city, where traffic congestion problems are usually the most severe. However, as congestion worsens and other alternatives are exhausted, it Is quite possible that pricing strategies will become more attractive.

Impacts of the Pricing Emphasis alternative depend on the elasticity of substitution between the. auto and alternative modes, between peak and off peak travel, and between central city vs. other location destination choice. The first is easily captured by mode choice model estimation within the UTP system. The second is more difficult, since most model estimations are for the peak period only. It would be possible to estimate the shift to off peak travel outside the model, and then reduce peak trips a corresponding amount within the model. The third response would require a redistribution of trips based on new zone to zone generalized travel costs. Long run effects could be approximated by redistributing land use activities based on the new travel friction factors.

5.3.2 Direct Linkage

This alternative focuses primarily on new development, and on the second set of favorable conditions identified above. It assumes that all of the necessary transportation infrastructure (necessary = infrastructure required to serve travel demand at an acceptable level of service under current pricing, policies) is financed through property taxes and development charges, and that approval of new development is contingent upon provision of adequate infrastructure. It also assumes that adequate right of way for capacity improvements is available outside the central city, and that current trends in transit service provision and auto pricing policy continue.

Additional capacity required to bring existing development to an acceptable level of service would be financed via an across the board property tax increase. New development would "pay its own way" via additional taxes. These charges would have the effect of increasing the relative costs of new suburban locations.

This alternative does not directly manipulate travel demand; rather, it represents one way of providing the infrastructure necessary to continue current trends in travel behavior. Its impact on travel would be indirect. The relative cost of (suburban) housing would rise, real incomes would fall, and thus (all other things being equal), travel would decline. It is also possible that this alternative would have a concentrating effect, making central city locations more attractive. It should be noted, however, that since travel demand is highly inelastic, the impact on travel would be much smaller than the impact on housing price.,

This alternative represents a growing trend toward developer contribution requirements which pass infrastructure costs to the end consumer (home buyer, lessee) via higher real estate purchase and rental prices. Analysis of this alternative would provide insight on the magnitude of cost increases that would result from extensive application of this policy, and would also provide an opportunity to examine its equity implications.

Testing this alternative would be rather difficult, as the land cost impacts of the taxes would have to be estimated. This would require a dynamic model that incorporates land prices as well as transport prices, as for example the model developed by Anas for the Chicago area (Anas, 1983).

5.3.3 Land Use Controls

This alternative is based on the idea that cluster development is more efficient. It is assumed that the regional authority has sufficient control over land use to designate centers where development is encouraged and to limit development in all other areas. This is essentially the Toronto model, where development controls are used to create high densities and thus encourage a higher level of transit use.

Transit use is further enhanced by providing high quality service: frequent headways and exclusive rights of way for linehaul service. This strategy is advocated by a substantial proportion of the planning community as a way to reduce dependence on the automobile and reduce fuel consumption (Pushkarev, Zupanand and Cumelia, 1982).

The feasibility of this alternative is questionable, since it assumes a level of land use control that has never existed in the U.S., and it runs counter to the decentralization process described earlier. The alternative would require land use to be controlled at the regional level, thus stripping local government of one of its key powers. It is questionable whether such a shift in authority is feasible. In addition, controls on land use would have to be quite extreme in order to direct development patterns away from the existing strong decentralizing forces.

This alternative would provide valuable information on the extent to which these constraints would affect travel behavior, given U.S. demand characteristics. Since land use is constrained, the impacts of the policy could be modeled without considering land use feedback effects. The policy can only affect mode choice and trip distribution. This alternative would provide insight on the relative efficiency of transit and auto when transit is given the most favorable circumstances.

5.3.4 New Technology

This alternative is based on the premise that individualized transportation will continue to dominate all other modes, and that new technology will be employed to reduce the resource cost of auto use in the future. As a rough approximation of technology improvements, automobiles are assumed to be 25% smaller and 50% more fuel efficient than the existing vehicle fleet. The existing road system's capacity (that is, existing right-of-way) will increase by a proportionate amount. Commensurate reductions will not occur within the truck fleet, necessitating a separate truck transport system within metropolitan areas. For the purpose of analysis, it is assumed that the truck transport system will be financed from truck user fees and located within existing highway rights of way. On the arterial system, specific truck routes would be designated. Furthermore, autos will use "clean fuels" and thereby comply with air pollution reduction requirements. There are no additional controls on land use and no changes in auto pricing policy.

This alternative may in fact represent the most likely scenario of the future. It is premised on an established technological trend toward developing more efficient personal vehicles and highways. Substantial research is already underway to use automated vehicle control technology to. increase highway capacity by reducing vehicle headways (for example, the Pathfinder project sponsored by FHWA and CALTRANS), to use real-time traffic information to optimize vehicle routing, and to develop the "urban car."[5] It potentially eliminates the two major barriers to more extensive auto use: prohibitive infrastructure costs and negative environmental impacts. It can be expected to have a significant decentralizing effect and to result in more total travel than any of the other alternatives.

Analysis of the impacts of this alternative could provide estimates of the infrastructure requirements of continued dominance of the automobile under the most favorable conditions. That is, this alternative represents the optimistic view of continued dominance of the private auto.

5.3.5 Combining Alternatives

The four alternatives have purposely been made as simple as possible. They may be considered the 'basic alternatives," each one representing a very different planning strategy. The results of the analysis can be used to develop additional alternatives representing combinations of specific elements from the basic alternatives. Sensitivity tests could be used to identify the most promising elements. In this way, possibilities for achieving a better match between land use and transportation can be identified.

The four alternatives have also been purposely made as extreme as possible. As discussed earlier, extreme alternatives provide the best estimates of the bounds of both positive and negative possible outcomes. They thus can establish the limits within which the best possible alternative are most likely to be found. The four basic alternatives should provide extensive information on the comparative advantages and disadvantages of these different approaches, and should increase our understanding of the total effects of different approaches to improving transportation system efficiency.

ENDNOTES

5. The literature review is presented In "Literature Synthesis: Transportation and Urban Form, "October 1989, prepared by Genevieve Giuliano for the Federal Highway Administration. A copy may be obtained by calling Terry Anderson at (202) 366-0182.

6. For examples of statistical measures that describe urban form characteristics, see Schneider et al, 1983

7. The fact that fewer decisions are involved in land use development does not imply that the development process is any less complex. Indeed. environmental review and public participation requirements have added complexity to the development process.

8. Electronic sensor-based telling equipment is already being use in test applications. Such equipment is also scheduled for implementation on California's three new planned toll facilities.

9. For example, General Motors and others are conducting research on the "lean car" -a two person vehicle configured so that the width of the car requires only half of the current typical 12 foot lane width.

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Description of Example Empirical Study	
Author:	Cervero, R. (1988)
Title:	*Jobs-Housing Balancing and Regional Mobility*
Purpose:	Determine impact of relative distribution of population and employment on journey to work and congestion.
Samples:	1980 census tracts in San Francisco Bay area (28 census tracts outside cities of SF, Oakland, and San Jose)/ residence and employment data)
Variables:	residents working outside of zone of residence:
	-- # of employed residents, # of employees -- # of employed residents and employees in service and professional occupations -- median cost of single family house -- # of households with 2 or more cars -- ordinal rating of zoning for residential uses, travel time
	mode share:
	-- % of work trips by walking or cycling -- employees per on site company sponsored van in operation -- employees per on site housing unit -- % of total floor space in retail use
	freeway LOS:
	-- peak hour service level on freeway -- commercial, office, and industrial floor space -- employees per acre, employees per on-site housing unit
Methods:	basic gravity model, stepwise regression, stepwise regression
Results:	-- the amount of residentially zoned land and the cost of housing were significant locational determinants -- where there are more jobs than on-site housing units, share of commutes by foot or bike falls -- suburban centers with large amounts of office of commercial floor space, high employment densities, large job-housing imbalance, the major freeways tend to be most congested

Description of Example Empirical Study	
Author:	Edwards, J.L., and Schofer, J.L (1976)
Title:	*Relationships Between Transportation Energy Consumption and Urban Structure: Results of Simulation Studies*
Purpose:	Analyze relationships between urban structure transportation network, and energy consumption in passenger travel.
Variables:	population, employment, labor force participation rate, density patterns and shapes, interzonal impedance factor by trip type, trip rates per capita by trip type, automobile, automobile-transit, transit (transportation technology), highway speeds, transit route
Sample:	37 hypothetical cities
Method:	Simulation with models including Lowry model.
Results:	Wide variation in energy requirements for differing urban structures, i.e., structures with sprawling land use patterns have larger energy requirements than relatively compact structure. Cities using only the automobile have much larger energy requirements than relatively compact structure. Density patterns and the relative importance of automobile make energy requirements and accessibility different in structure with same shape. The concentric ring is the most energy intensive city type.

Description of Example Empirical Study	
Author:	Gordon, P., Richardson, H., and Wong, H.L (1986)
Title:	*The Distribution of Population and Employment in a Polycentric City: The Case of Los Angeles*
Purpose:	Analyze relationships between urban structure and travel characteristics.
Variables:	population density, employment density, population, work trips
Sample:	403 census tracts in five major counties for 1970 and 1980 (1980 employment only).
Method:	non-linear least square via Newton-Raphson algorithm
	two patterns of employment distribution

Results:	-- spatial concentration around a few major employment centers -- High degree of general job dispersion Urban structure best described as polycentric; work trip shorter in suburban areas.

DESCRIPTION OF EXAMPLE EMPIRICAL STUDY	
Author:	Hanson, S. and Schwab, M. (1987)
Title:	*Accessibility and Intraurban Travel Behavior*
Purpose:	Analyze relationship between accessibility and intraurban travel behavior.
Variables:	travel distance for work, trip frequency, trip complexity (proportion of trips according to the # of stops), travel distance for discretionary travel, mode use, travel in conjunction with work trip, size of activity space
Sample:	adult members of 278 households in Uppsala, Sweden (stratified random sample)
Method:	numerical cross-tabulations
Results:	Accessibility has relatively weak positive association with travel characteristics. Strongest relationships - accessibility with the % of non-motorized trips, with non-work travel distances, and with size of activity space. Socio-demographic characteristics are more influential on travel behavior.

DESCRIPTION OF EXAMPLE EMPIRICAL STUDY	
Author:	Kain, J., and Fauth, R. (1977)
Title:	*The Effect of Urban Structure on Auto Ownership and Journal to Work Modes*
Purpose:	Analyze mode choice to work as function of auto ownership, residence characteristics, modal characteristics, and urban structure.
Variables:	individual work trip mode, housing type, housing age, transit vehicle mile/ population, highway route-miles, autos, households, job location (CBD, central city, other)
Sample:	125,050 white households with one worker, U.S., 1970
Method:	logit model with OLS
Results:	Urban structure characteristics, residential characteristics, modal characteristics have

	significant impact on auto ownership and mode choice.

DESCRIPTION OF EXAMPLE EMPIRICAL STUDY	
Author:	Newman, P., and Kenworthy, J. (1988)
Title:	*The Transport Energy Trade-Off: Fuel-Efficient Traffic vs. Fuel-Efficient Cities*
Purpose:	Analyze relationship between gasoline consumption and urban form.
Variables:	vehicle fuel consumption, distance from CBD, average speed, per capita fuel use (fuel use by residents), average trip length
Sample:	6 study areas (aggregated from 38 zones) in Perth, Australia 15,000 trips in Perth, Australia.
Method:	Simple regression analysis, comparative study
Results:	Locational factors are more important in the overall determination of fuel use than the effect of congestion on individual vehicles.

Description of Example Empirical Study		
Author:	Payne-Maxie Consultants (1980)	
Title:	*The Land Use and Urban Development Impacts of Beltways Final Report*	
Purpose:	determine land use and development impacts of beltways	
	Comparative Statistical Analysis	Case Study
Variable:	beltway influence data, central city employment, trade, population, travel and energy consumption patterns	In addition, evaluation of economic distress data retail sales data
Sample:	27 US SMSA cities with limited access beltways and 27 US SMSA cities without beltways	8 selected SMSA cities with beltways
Method:	Multivariate analysis including regression analysis, and descriptive statistics	Case study based on descriptive statistic and route and corridor studies, etc.
Results:	Beltways may have had some influence on metropolitan development patterns. Beltways exhibit no significant statistical	Impact of beltways depends on local conditions and coordinated planning between private sector,

	relationship with the growth and distribution of population and residential patterns, retail sales, or employment patterns and moving patterns, and the suburbanization of minority households.	local, and regional agencies.

DESCRIPTION OF EXAMPLE EMPIRICAL STUDY	
Author:	Pushkarev, B., with Zupan, J., and Cumella, R. (1982)
Title:	*Urban Rail in America*
Purpose:	Determine conditions for cost effective rail mass transit.
Sample:	(historical) U.S. cities, and world cities
Variables:	railway related data including miles of lines, number of users, railway operating data including CBD, employment, non-residential floorspace, gross and net population density, trip patterns, travel distances, etc.
Method:	descriptive statistics, regression analysis, model building for a data base
Results:	Express buses are more of a competition with light rail than with rapid transit.

THE IMPACTS OF ALTERNATIVE URBAN DEVELOPMENT PATTERNS ON HIGHWAY SYSTEM PERFORMANCE

Patrick DeCorla-Souza, A.I.C.P.

INTRODUCTION

This is an extensive body of theoretical literature discussing the link between urban development patterns and transportation. Urban planners have long recognized that development patterns influence travel demand and congestion levels, and transportation system supply and performance characteristics in turn influence development patterns.

One important question that is being asked as a result of worsening traffic congestion is: What is the potential contribution of development patterns to a moderation of highway travel demand and traffic congestion levels in urban areas? The Federal Highway Administration (FHWA) south to answer this question through studies of the impacts of alternative development patterns in U.S. cities. The studies were done with limited resources under FHWA sponsorship by the Metropolitan Planning Organization (MPOs) in four urban areas --Baltimore, Dallas, Washington, D.C., and Seattle. This paper documents the results of their efforts and draws some general inferences from their analyses.

A second question of interest particularly to the environmental community is: What are the development effects of transportation system (particularly highway) supply and performance characteristics? FHWA is currently pursuing a multi-year study on the feedback effects of transportation system performance on development patterns and will report one the results as they become available.

BACKGROUND

Urban development patterns can be studied at the micro level, at the macro level or in combination. Micro level studies look at the impacts of localized strategies. For example, the physical layout of new developments can be designed to create circulation patterns and environments conducive to travel by transit, bicycles, and walking. In addition, developments can be designed with mixed land uses to spread travel to them throughout the day; different types of land uses have different travel peaking characteristics. Mixed use developments can increase use of car-pools, van- pools and transit since people will not need their cars during mid-day if service establishments are within walking distance. Mixing employment and residential land uses also provides opportunities for those who wish to live near their work places, encouraging bicycling and walking trips.

Macro level studies look at the regional impacts of urban form alternatives. For example, development in a region can be either concentrated or decentralized. It can be confined to transit accessible corridors, or it can be dispersed to the periphery of urban areas where spare highway capacity is available. Employment can either be concentrated in a few major activity centers, or it can be distributed to many small activity centers. Jobs and housing may be balanced within sub-areas, or disproportionate amounts of housing may be developed in the exurbs and fringes of urban areas to take advantage of lower housing costs, with few jobs within reasonable commute distances.

The studies done under FHWA sponsorship in the four U.S. cities were macro-level studies which sought to investigate the potential of alternative patterns of future growth to affect highway system performance. This was done by computerized simulation of their travel consequences in a target year in the long range future (2010 or 2020). Each MPO developed its own set of alternative long range urban development patterns for analysis. They compared the alternatives to development forecasts previously adopted by their policy bodies in order to draw conclusions about the relative impacts of the alternatives on travel demand and highway system performance.

The studies were done using the traditional four-step travel demand modeling process to simulate travel demand and congestion impacts. Baltimore, Dallas and Washington, D.C. varied only land use inputs into the modeling process, keeping transportation system characteristics the same as that used in base case. Seattle tested combinations of land use and transportation system strategies. The results of their studies are summarized in the following four sections.

BALTIMORE

The Baltimore study looked at the effects of three alternative patterns of future residential development, keeping future growth in employment concentrated in a few activity centers. The alternatives were compared to a base scenario representing household and employment location distributions which were essentially a composite of forecasts provided by the six local jurisdictions which comprise the Baltimore region. The forecasts had been adopted by the Regional Council.

The first alternative concentrated regional household growth anticipated between 1990 and 2010. A significant portion of anticipated growth was allocated to areas within the region's "development envelope". The second alternative decentralized household growth, assigning a significant portion of regional household growth to areas outside the development envelope. The third alternative allocated regional household growth only to those areas with a high level of transit accessibility. In all three alternatives, anticipated regional employment growth has assigned to existing activity centers, creating more intense employment clusters. The existing plus programmed transportation network was assumed for each alternative and the base.

The redistribution of the 1990-2010 increment of growth changed the proportions of total horizon year regional households and employment within the development envelope by less than 3% as indicated in Table 1. Over the twenty year period 1990-2010, total households are projected to grow by 24% over the 868,000 households existing in 1990 and total employment was projected to grow by 17% over the 1,357,000 jobs existing in 1990. These increases were not high enough relative to the 1990 base to significantly affect existing patterns of concentration.

The analysis indicated that the region-wide transportation impacts of the alternatives would likewise be relatively small. The results of the analysis are summarized in Table 1. Person trips do not very much between alternatives. The variation in vehicle trips reflects the greater propensity to use transit and ridesharing modes as urban development is concentrated.

The impacts with respect to region-wide vehicle miles of travel (VMT) and congestion indicators were also relatively small, although larger than vehicle trip impacts. The highway system performed the best under the centralized alternative severely congested VMT and severely congested lane miles were both reduced by more than 1.5% relative to the base. This improvement was primarily due to the reduction in total region-wide highway travel demand, an almost 1% reduction in region-wide VMT.

Highway system performance deteriorated relative to the base under the other two alternatives. Under the decentralized alternative, severely congested VMT and lane miles increased by 1.6 and 3.0% respectively, due to the increase in total VMT of almost 2%. Under the transit oriented alternative, severely congested VMT increased by over 2%, even more than under the decentralized alternative. However, the congestion was more localized, occurring on fewer lane miles than under the decentralized alternative.

The results of the Baltimore study suggest that concentrations of residential development can benefit highway system performance and reduce new highway capacity needs. Concentrations of residential development within areas with good transit access may not reduce highway capacity needs relative to base policies, although they could reduce new highway capacity needs relative to a decentralized pattern of development. Apparently, the reduction in region-wide vehicular travel demand with the transit oriented alternative does not appear to reduce new highway capacity needs because vehicular travel demand is channeled into locations with little spare highway capacity.

DALLAS

The three alternative development patterns studied in the Dallas urban area closely paralleled Baltimore's alternatives. Redistribution of growth in the Dallas alternatives was restricted to growth projected within the service are of the Dallas Area Rapid Transit (DART) system. As in Baltimore, the first alternative concentrated employment growth within predefined activity centers and distributed anticipated residential growth to zones with a specified distance from each activity center. A second alternative allocated employment and residential growth to currently uncongested areas, which are in dispersed locations. This alternative was designed to assess the impact of confining new development to areas with under-utilized roadways. The third alternative was transit oriented--it concerned growth, both employment and residential, within a 3.5 mile radius of Dallas Area Rapid Transit (DART) rail stations. The alternatives were compared to forecasts from the year 2010 transportation plan for the region. Table 1 summarizes the result of the comparisons. Employment growth over a 25 year period (1986-2010) in the DART service area amounted to about .6 million or about 30% of total year 2010 employment in the service area. (The analysis area was expanded slightly to take in uncongested areas for the second alternative, owing to a lack of sufficient uncongested areas within the DART service area). Significant redistribution of employment growth occurred with all three alternatives, as indicated in Table 1.

Population growth reallocated within the analysis area amounted to about 20% of total year 2010 population. For the first two alternatives, the change in the distribution of this population growth indicated in Table 1.

With respect to travel demand and congestion indicators, the "Dispersed Growth in Uncongested Areas" alternative was the only one to reduce VMT significantly (by about 5%), as well as produce significant improvements in level of service on the highway system. Average speed increased by 2%, the percent of travel time spent in delay was reduced by 4% and the percent of roadways congested was reduced by 10%.

The transit oriented alternative failed to reduce VMT or improve highway levels of service. Reductions in VMT were insignificant due to relatively insignificant increases in transit ridership (about 35,000 additional linked transit trips region-wide). Higher congestion levels were in the result of higher employment concentrations around the Dallas CBD, forcing the additional trips to these areas to travel on already congested facilities.

The activity center oriented alternative did not change either VMT or levels of congestion significantly. The somewhat slower average speed and increase in delay time probably reflect the effects of higher volumes of traffic being concentrated in the vicinity of activity centers.

WASHINGTON, D.C.

A somewhat different approach was taken in and selection of alternative urban development patterns for the Washington, D.C. area. Two alternatives were selected. The first sought to promote a closer balance between employment and housing growth within the region. The second built upon the first and additionally sought to promote transit use by concentrating employment growth in areas of high transit accessibility.

The alternatives were compared to a base reflecting adopted 2010 forecasts which were based on "pipeline" development proposals, zoning, available land and other factors and has been developed in cooperation with local jurisdictions. The results of the comparisons are presented in Table 1.

TABLE 1
IMPACTS OF ALTERNATIVE DEVELOPMENT PATTERNS IN FOUR URBAN AREAS

		Impacts of Alternatives (% Change)		
BALTIMORE	Base Case (Adopted)	Alt 1 (Centralized)	Alt 2 (Decentralized)	Alt 3 (Transit)
% households within development envelope	87.8	+1.8	-1.8	+2.8
% employment within development envelope	94.2	+0.5	+0.5	+0.5
Daily internal trips: Person	7,867,500	-0.3	+0.5	-0.3
Vehicle	5,551,700	-0.6	+0.6	-0.5
Daily Travel: VMT	54,757,200	-0.9	+1.8	-0.7
Average speed (mph)	20.7	0.0	-1.9	-4.8
Severely congested VMT	17,093,400	-1.7	+1.6	+2.3
Severely congested lane mi.	1,280	-1.6	+3.0	+1.0
DALLAS	Base Case (2010 Plan)	Alt 1 (Activity Centers)	Alt 2 (Dispersed)	Alt 3 (Transit)
Employment Growth: In activity centers	173,848	+135	--	--
In uncongested areas	256,620	--	+103	--
In areas within 3.5 mi. of rail	378,443	--	--	+40
Population Growth: In activity ctr. & tributaries	278,817	+13	--	--
In uncongested areas	355,737	--	+5	--
In areas within 3.5 mi. of rail	130,861	--	--	+143
Daily Travel: Vehicle trips	7,221,024	-1	-1	-1
Average speed (mph)	30.9	-2	+2	-3
VMT	63,048,000	0	-5	0
% travel time spent in delay	36.6	+3	-4	+5
% roadways congested	20.3	0	-10	+2
WASHINGTON, D.C.	Base Case (Adopted)	Alt 1 (Jobs/ Housing)	Alt 2 (Transit)	
Employment Growth: In emp. growth areas	604,000	0	+7.3	
In high potential transit use areas	165,000	0	+100.0	
In whole region	713,000	0	0	
Household Growth: In emp. growth areas	143,000	+181	+181	
In balance of region	125,000	-47	-47	
In whole region	268,000	+75	+75	
Regionwide daily travel: Vehicle trips	12,020,000		+5.7	+4.7
VMT	103,800,000	+1.0	+1.3	
Avg pk hr speed (mph)		16.9	+1.2	+1.8
Travel per household: Vehicle trips daily	6.8	-5.0	-6.0	
Average trip length	8.6	-4.5	-3.2	
VMT daily	59.0	-9.2	-8.8	

Employment growth projected over a fifteen year period (1995-2010) amounted to 713,000, a 27% increase over the 1995 base of 2,605,000. The distribution of employment growth was unchanged for the first alternative. For the transit oriented alternative, seven high employment growth areas which have superior transit accessibility were allocated twice the number of new jobs previously allocated. The adopted 2010 household forecasts for the region indicated an 18% increase above the 1995 base of 1,489,000. The increase amounted to 268,000 households, which would be about 200,000 fewer households than would be needed region-wide in order to balance the 713,000 new jobs projected, assuming 1.5 workers per household. To minimize commuting into the study area from external counties, an additional 200,000 households were added to the two alternatives, resulting in an increase of 75% above the household growth in the base. (Note: these households are assumed to be located outside the study area in the base).

Jobs and housing were also balanced within sub-areas. To balance the 604,000 new jobs projected within 29 employment growth areas, about 402,000 new households were needed, whereas only 143,000 were allocated to these areas in the base. The two alternatives sought to achieve a balance in those areas by drawing 200,000 households from outside the study area (as previously discussed) and the balance of 59,000 from other areas within the study area.

The region-wide increase of 200,000 households amounted to an increase of 11% above the base total households of 1.75 million. In spite the increase, region-wide VMT in the alternatives exceeded base VMT by only about 1% (about 1 million VMT). This was the result of reduced vehicle trips per household due to greater transit use, and shorter average trip lengths due to greater proximity of housing to jobs. The 200,000 new households, had they located outside the area, would have generated about 10 million VMT, about 5 million of which would have been outside the study area. This 5 million VMT was saved outside the area. The two alternatives, at a cost of about a 1 million increase in VMT inside the study area. The transit oriented alternative did not appear to increase the effectiveness of the jobs/housing balance alternative with respect to VMT reduction.

SEATTLE

Seattle's base case consisted of a composite of local growth patterns determined by each city and county in the region. In the base, new employment was scattered in office parks, shopping malls and strip centers, with some new employment in major downtown areas. Most new housing development occurred in suburban areas. Transportation system improvements included a regional rapid transit system and modest expansion of highway capacity.

The alternative strategies consisted of changes to both the land use patterns as well as to transportation system characteristics. The first, a Major Centers alternative, concentrated new employment growth in a few major centers and encouraged higher density residential development within walking distance of major transit access points. Transit investments were emphasized, including HOV lanes. Highway capacity expansion was restricted to critical links, and transportation demand management (TDM) programs were supported.

The second alternative was a Multiple Centers alternative. It concentrated new employment and housing growth in a relatively large number of centers, with a balance of jobs and housing within each center's area of influence. Transit emphasis was high, although less than the Major Centers alternative. Highway capacity expansions involved 60% more new lane miles than in Major Centers, while TDM programs were similar.

The third alternative was a Dispersed Growth alternative. It dispersed employment and housing into newly developing areas where new highways or major highway widening could be provided, or where existing highways have spare capacity (similar to the Dispersed alternative in Dallas). Only moderate investments in transit were included, sufficient to maintain present levels of service. Highway capacity expansions included extensive radial and circumferential highways to serve the newly developing areas. TDM measures were supported.

The comparisons of the alternatives with the base are summarized in Table 1. Over the 30 year analysis period (1990-2020) population was projected to grow by 52% over the 1990 population of 2.7 million, while jobs were projected to grow by 66% over the 1990 employment of 1.3 million. None of the alternatives were expected to materially affect the rate or amount of region-wide growth. The relative variation among the alternatives with respect to the distribution of growth is indicated by the changes in the growth rate of King Country, the central county, as shown in Table 1.

Variations in region-wide travel demand are relatively small - ranging from a 4% reduction in VMT under Major Centers to a 3% increase with Dispersed Growth. As in the Dallas study, concentration of growth in a few centers (Major Centers) was found to increase congestion levels, especially in the vicinity of the centers, and to reduce average speeds. Concentration of growth in many centers (Multiple Centers) on the other hand was found to reduce overall delay and congestion somewhat. But there was no change in average regional speeds, and a more detailed review of the network indicated that congestion in critical travel corridors was significantly higher, particularly in suburban and rural areas. The Dispersed alternative was less effective in reducing congestion than Multiple Centers, probably due to higher VMT.

INFERENCES FROM THE STUDIES

Some general inferences from the above analyses are discussed in this section.

The studies suggest that concentrating urban development may reduce vehicular travel demand and congestion, as indicated in the Baltimore study. However, when there is excessive concentration at a few high density centers, high congestion levels may be expected in the vicinity of the high-density activity, centers, as indicated in the Dallas and Seattle studies.

Concentrating development in areas with superior transit access does not appear to shift sufficient travel to transit modes to reduce congestion levels, although some reductions in region-wide VMT may be achieved. However, vehicle trips may have been overestimated in high density zones due to limitations in the study methodology. Trip production rates in regional models are generally not sensitive to zonal density characteristics. Also, the shift to transit may have been underestimated by the modeling approach used in three of the four studies, since parking cost increases and improvements to transit service (such as improved since frequencies or coverage made possible by increases in demand, or feeder bus services) were not considered. Nor were the mode shifts to rail which could result from greater highway congestion. Further analysis is needed to determine whether improvements to transit service (such increases in parking costs could shift sufficient numbers of peak period highway users to transit or ridesharing modes to significantly affect peak period congestion levels and new highway capacity needs in these high density areas.

Dispersed growth patterns may reduce congestion levels if growth is directed to areas where spare highway capacity exist. However, total travel demand (VMT) will rise. If growth is not properly directed, both VMT and congestion levels will rise, as indicated in the Baltimore study.

Providing affordable housing within current urban boundaries and in proximity to employment growth areas can significantly reduce highway travel demand (VMT) in the broader region (i.e. including surrounding counties and exurbs). The Washington, D.C. study indicates that VMT per household can be reduced by as much as 10%. However, BMT and congestion levels could rise within the urban boundaries due to the accommodation of housing units which would otherwise be outside the urban boundary.

Macro level land use strategies that simply relocate future growth appear to have relatively little impact on highway travel demand. Region-wide VMT did not change by more than 2% in Baltimore, 5% in Dallas, and 4% in Washington, D.C. and Seattle. While region-wide VMT may not be greatly affected, congestion levels can be influenced to a much greater extent because new development can be either forced into existing dense areas with little developing areas where spare capacity exists. Changes in average congestion measures of as much as 10% were observed in the studies.

The relatively small impacts on travel demand may be explained by the fact that three of the four studies did not look at transportation infrastructure investments and TDM measures in combination with land use alternatives, and none of the studies looked at further changes that could be induced by micro-level land use strategies in combination with TDM measures and infrastructure investments. Currently, regional models generally cannot be used to analyze urban design options. An FHWA research project is currently underway to improve the ability to model the impacts of micro-level strategies and combined strategies.

CONCLUSIONS

The four studies, although of limited scope, were important step in improving our understanding of the general magnitude and direction of the impacts of macro-level land use strategies. Limited study resources precluded extending the scope of the studies to get more refined impact estimates based on recursive modeling approaches, for example by including the effects of transportation system supply and performance characteristics on trip generation, trip distribution, land use location decisions and mode choice. Research is underway at FHWA to develop such modeling enhancements for wider application in urban areas.

The result of the study suggest that urban areas should add macro-level land development decisions to the tool box for congestion management. Regional land use planning <u>can</u> make a significant difference.

However, if urban areas are to succeed in implementing such region-wide strategies, they will have to enhance their intergovernmental structures and processes to facilitate the key policy decisions needed to guide urban development into patterns which are more effective in reducing congestion.

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RESULTS OF LITERATURE SURVEY AND SUMMARY OF FINDINGS: THE NATURE AND MAGNITUDE OF SOCIAL COSTS OF URBAN ROADWAY USE

for
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1. INTRODUCTION

There is a growing interest in bringing to transportation, the same set of principles and incentives as used in the privately operated economy. In an article on congestion pricing, Orski (1991) cites a report by the Bay Area Economic Forum contending that market-based approaches would bring about a more efficient and less costly means of achieving air quality standards than the current regulatory approaches of Southern California. Orski goes on to contend that this awakening interest in private market mechanisms is responsible for the revival of interest in congestion pricing.

Giuliano argues that establishing a pricing system that reflects the true cost of travel is a straightforward way of improving transportation efficiency in a report, <u>Relationships between Urban Form and Transportation: Implications for Long Range Planning</u>, to the Federal Highway Administration (Giuliano 1989).

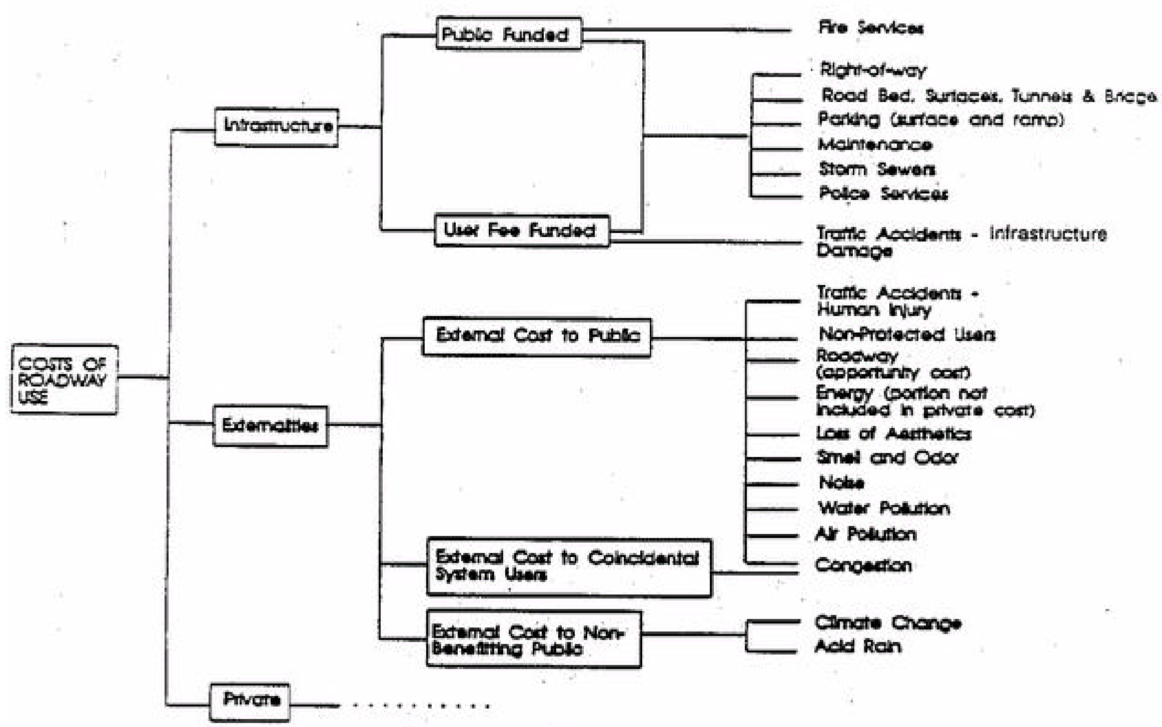
It is apparent that the interest in market-based approaches to transportation-related problems is correlated with the growing interest in the broader issue of social costs of highway use. It also appears that parallel developments in planning methods in electric utility planning (integrated least-cost planning) are influencing the field of transportation planning.

The literature discussing the nature and magnitude of social costs of highway use is surprisingly limited in certain respects, and extremely broad in others. However, the total volume of literature which explicitly adopts the formalism of economics in treating social costs of transportation is small considering the magnitude of the social costs and the importance of the highway system to the U.S. economy and to the fabric of contemporary American society.

Where social costs are explicitly addressed in economic terms, they usually focus only on particular aspects of transportation issues. For example, the Urban Institute recently completed a far reaching but focused study entitled "The Costs of Highway Crashes," which addresses both societal and social costs (FHWA 1991).

The societal cost of highways includes all of the cost categories shown in Figure 1 while the social costs are those noted under the externalities branch of Figure 1. There are very few studies which attempt to integrate all the different aspects of highway social costs into a comprehensive analysis of the social costs of highway use. In particular, there are a number of identifiable areas where, literature explicitly treating social costs in formal economic terms is very thin or absent altogether. For example, the literature provides very few economic cost estimates of the highway damage to surface and ground water resources despite widely acknowledged impacts resulting from storm water runoff, including oils and greases, road salt and sediment loadings, and deposition of air born pollutants. If indirect costs are considered, the damage to these water resources from leaking storage tanks containing transportation fuels, will add significantly to the total social costs of highway use.

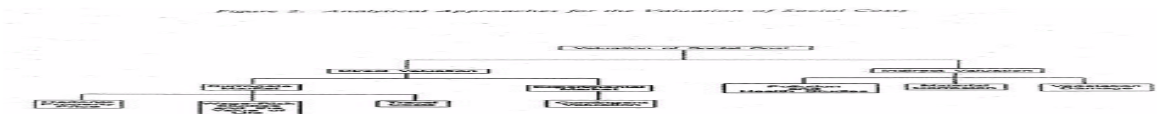
Figure 1. Taxonomy of Costs of Roadway Use



The literature that does not follow a formal economic treatment is immense and the coverage is very broad. The difficulty raised by this literature is that while it treats a wide range of issues pertinent to social costs, the material is not particularly amenable to summarization, particularly in terms that measure social costs or more narrowly lead to the establishment of efficient urban highway tolls. Efficient tolls are "tolls which would ensure that the price paid by the roadway user is equal to the increment of social and private costs resulting from the highway use" (FHWA statement of work).

This report on the results of the literature survey focuses primarily on the literature treating the social costs of highways in economic terms. The approach used in the report follows two "taxonomies" of the costs of highways. The first taxonomy shown in Figure 1 is of the elements of social costs while the second, Figure 2, delineates the economic approaches to measuring social costs.

The literature is summarized and assessed in qualitative terms. While it would be useful to systematically update the social costs of highway use based on the literature reviewed and current ongoing work, such an effort is beyond the scope of work. This report also provides two appendices. The first appendix lists the pertinent sources of social costs. The second appendix is an abbreviated listing of integrated resource planning literature which has been developed in the area of electric utility planning, but is of



relevance to transportation planning.

II. DEFINITIONS

Defining the nature and magnitude of social costs for the purpose of establishing urban highway tolls (or other pricing mechanisms leading to an efficient allocation of scarce resources to highways) requires a careful statement of definitions. An efficient highway toll would include social costs as conventionally defined plus other transfer payment costs which are external to the market transactions of highway use but which are currently paid for out of pocket. Road construction paid for by public funds such as property taxes is an example of a transfer payment cost which is paid for out of pocket as noted in Figure 1.

It is also important to distinguish between externalities imposed on individuals not using the highway system versus externalities that are imposed on individuals using the system coincidentally. Conventional external costs, as noted in Figure 1, include loss of aesthetics, odor, noise, water pollution, air pollution, climate change, etc. An externality that is primarily imposed on other coincidental users of the roadway system is congestion as is shown by the separate branch under externalities in Figure 1. However, congestion costs, such as interference with pedestrian movement, may also impact on non-system users as shown in Figure 1.

Completing the externalities portion of Figure 1, is the category called "external cost to non-benefiting public." This distinction is drawn to bring attention to the fact that some impacts such as acid deposition and climate change may impact populations that do not benefit from the mobility that is the source of the externality. Within the urban area, one can make a plausible argument that urban residents benefit, at least indirectly, from the travel of others. (If one considers the social costs of highway use, say at a national level, the boundary, between the public benefiting and not benefiting, changes. However, in a world where the vast majority of households do not own a motor vehicle, the issue of impacts on the non-benefiting public remains, particularly for climate change.)

The social costs included under the "externalities" branch of *Figure 1* are the primary focus of this literature review: The establishment of efficient prices, however, will also require the inclusion of other costs of the highway system which are not currently included in highway use prices. In Figure 1, these subsidies or transfers, include those identified as "public funded" costs under the "infrastructure" branch. These costs include road construction, bridge construction, signalization, repair, maintenance, storm sewer construction and maintenance, police services, right of way acquisition, and various planning and administrative costs associated with these services. The payment of these costs currently comes from both user fees and other, general revenue sources such as the property tax.

The "private" cost branch of the diagram is not delineated, but is included to indicate the complete picture of the costs of roadway use. Private costs include insurance costs and the pain and suffering of injuries and deaths which amount to enormous societal costs. The fact that these private costs are as large as they are and individuals still travel at their current rates is indicative of the benefits to society of highway use. While health costs and human pain and suffering are largely private costs, there are two aspects which are considered social costs in this literature review. The first relates to impacts on "non-protected" individuals such as pedestrians and bicyclists. The second aspect is the loss to society of individuals work related and non-work related production. These two social costs are included under externalities in Figure 1.

III. SUMMARY OF THE LITERATURE ON THE NATURE AND MAGNITUDE OF SOCIAL COSTS.

The evaluation is presented in two parts. The first part is an overall assessment of the state of the literature. This is then followed by a category by category review following the structure of Figure 1.

A. Overall Assessment

The state of knowledge of the social costs of highway use as reported in the literature is only fair at best. This conclusion reflects in part the size, numerous facets, and complexity of the topic. The definition and measurement problems are enormous. The overall size of the issue lends itself to segmented approaches.

The meager state of knowledge is also reflective of a prevailing lack of interest, until quite recently, in applying market principles to the pricing of highway use. After all, if market principles were not being applied, a segmented approach focusing on specific, important problems and corrections, i.e., reduction of accident occurrence and severity of injuries, made sense.

The net result is that there exists very few systematic economic treatments of the overall social costs of highway use and uneven treatment of the specific aspects. The work of Hanson (1992) and Ketcham (1991) are starting points for assembling an aggregate picture at the urban level or at the national level, of the social costs of highway use. The Hanson work explicitly excludes a number of social cost items that need to be developed. Coincidentally with the publication of that work, the Federal Highway Administration (1991) published a major study by Miller and others at the Urban Institute on the cost of highway crashes which provides considerable information to fill in some of the exclusions of the Hanson work.

The Ketcham work provides an estimate at some local and national levels of the total costs of transportation (S 1658 billion in 1990, which is equal to about one-third of the U.S. Gross National

Product). However, definitional questions as to what is an externality or social cost versus a private cost are left unanswered and need to be addressed.

Other aggregate studies have been done at the municipal level, including the work of Hart (1985) and Kinney (1991).

Recommendations for future research, developed further in Section V.C., point out the need to develop a national aggregate social cost estimate and to establish a set of highway social cost accounts, based on environmental accounting. Such work appears to be underway under the auspices of the Economic Analysis Division of the U.S. DOT Volpe National Transportation Systems Center. Such a set of accounts would provide time series data measuring developments in externalities, publicly funded infrastructure costs, and some private societal costs not routinely reported.

B. Categorical Costs

1. Externalities

Traffic Accidents

The health costs attributable to highway accidents have been the subject of recent work at the Urban Institute (FHWA 1991). This work is thorough and extensive. An issue not treated in the Urban Institute report but critical to this review, is which of the costs considered should be labeled social costs (and potentially chargeable to highway tolls), and which costs are exclusively private costs. An important cost, which in many instances can be considered a social cost, is the impact on non-protected users, i.e., pedestrians and bicyclists. This subject is treated in some depth in the European Literature (see OECD 1985). The issue of which of the societal costs are social costs would merit further research.

Roadway Opportunity Cost

The literature review found few studies presenting systematic economic estimates of Roadway Opportunity Costs. The issue is identified by Giuliano in an October 1989 report to the Federal Highway Administration, Literature Synthesis: Transportation and Urban Form (DTFH61-89-P-00531). Because this is a complex issue of past decisions and estimating alternative land uses and their value, this does not seem to be a particularly promising area for research with limited research funds.

Energy (Portion Not Included in Private Cost)

The issue of non-private energy costs is largely one of the tax treatment of the oil industry. The size of the tax benefits are reasonably well known and do not make up a large cost item (see Hanson 1992). The indirect environmental impacts and hence social costs of oil and natural gas production are much larger, with both routine and episodic aspects (e.g., the Exxon Valdez spill in the Prince William Sound).

As a matter of convention in this review, studies estimating **indirect effects were not included** in the literature reviewed.

Loss of Aesthetics

Loss of aesthetic values results from the alteration and influence of highways on urban and rural landscapes and from visibility losses attributable to motor vehicle emissions. While there are qualitative discussions of aesthetic loss, this review did not find systematic attempts to place an economic value on aesthetic losses. The loss of visibility has been evaluated in research, notably Crandall et. al. (1986) and Freeman (1982). Current work dealing with visibility losses (not associated with transportation sources) in the Grand Canyon has arrived at some very high estimates of damages using contingent valuation. Such approaches are controversial and it would not seem to be a high priority area for work focused in the direction of establishing urban tolls.

Smell and Odor

The literature provided no economic estimates of the social cost of smell and odor from highway sources beyond qualitative treatment.

Noise

The primary references in the literature approach valuation and noise impacts by associating the loss of property values with noise levels, using hedonic property price approaches. The difficulty presented by this literature is that it focuses only on specific highway segments and conditions. There were no reported attempts in the literature to derive urban-wide values other than Ketcham (1991).

Water Pollution

Water pollution associated with highway construction and use is frequently addressed in the literature. There is little in the way of economic evaluation of the impacts, however, beyond the work of Murray and Ernst (1976).

Air Pollution and Climate Change

The social costs of air pollution are possibly among the three largest categories of social costs of highway use. Two leading categories are accidents and congestion costs. The importance of the subject is reflected in the Clean Air Act changes in 1991. The literature, however, demonstrates that there is still considerable uncertainty on the cost of air pollution associated with transportation.

The literature review found a few recent studies attempting to update transportation related social cost estimates for air pollution since the 1970's and early 1980's. Some recent estimates are provided by MacKenzie et al. (1992) which use a $10 billion per year estimate. The authors consider this estimate to be conservative, citing the work of Sperling and DeLuchi (1989) which cite a range of $10 to $200 billion, and the American Lung Association (1989) who estimate costs due to pollution at $40-50 billion from all sources based on health care costs and work time lost. Ketcham (1991) reports $30 billion for health care costs alone due to transportation air pollution.

Some recent studies have looked at the benefits of air pollution control in the California South Coast Air Quality Management District (R.D. Rowe et al. 1986; J.V. Hall et al. 1989; and A. Nichols and D. Harrison, Jr. 1990). The estimated benefits from pollution reduction with the district plan ranged from $2.4 to $20 billion per. year by the year 2010, for all sources, including transportation. In evaluating those studies for the district, Krupnick and Portney (1991) arrived at a wide range of estimates of up to $4 billion. In the same study, Krupnick and Portney found a range of benefits nationwide of $250 million to $1 billion for volatile organic compound (VOC) emissions control I only to reduce ground level ozone.

This national study was based on an Office of Technology Assessment Study (1989), which excluded transportation control plans, and considered acute health effects only.

Various difficulties in using these studies to estimate transportation damages include:

- Some do not distinguish between transportation-related damages and other damages;
- Some consider the benefits of emissions reduction, not the total cost of damage from all emissions present;
- Some do not estimate damages from all emissions, particularly the study by Krupnick and Portney.

If global climate change is included under air pollution social costs, then air pollution social costs could be much greater. The climate change literature (e.g., see Abrahamson 1989) indicates considerable scientific uncertainty as to the changes in climate and sea level that may occur. It is well established that atmospheric carbon dioxide concentrations are increasing and that the ozone layer is being depleted with holes appearing over the poles. It is less certain what. the climate consequences will be but there is considerable literature suggesting significant changes are possible. Some of the studies indicate massive economic disruption and damage. Transportation is one of the major contributors to global carbon and CFC (chlorofluorocarbons) emissions, important precursors to climate change.

<u>Congestion</u>

Congestion costs are large and rapidly growing in many large urban areas. Ketcham (1991) uses various sources including the 1982 FHWA Cost Allocation Study, to produce a national estimate for congestion costs for 1990 of $168 billion. Hanks and Lomax (1989) and DeCorla-Souza and Kane (1991) assess costs for specific cities and/or specific highway facilities in urban core areas and urban fringes.

<u>Acid Rain</u>

Acid rain is a growing concern in the Northeast and Eastern Canada, and more recently in parts of the Western U.S. Although sulfur species are the most important precursors, nitrogen oxides are the second largest and their emissions are strongly associated with motor vehicles. As total sulfur emissions decline nationally, the role of nitrogen oxides may become more significant. As damage estimates are developed, attention should be given to the transportation contributions.

2. Publicly Funded Infrastructure Cost

Publicly funded infrastructure costs represent large transfers from society in general to highway users. The benefits of the transfer increase with increasing private use of highways.

Recent forecasts by FHWA (1992) estimate that highway user fees will account for 61 percent of the $80 billion in highway receipts for Calendar year 1992. Of this total, $19 billion or 23 percent of highway receipts are estimated to come from property taxes, general fund appropriations and other taxes and fees, representing a significant transfer.

An increasingly popular theme in the literature is that if market principles are to be applied to transportation, then these infrastructure costs should be born by highway users along with the social costs. While there is a significant body of information on these costs at the federal level (see for example FHWA 1992 and the discussion of DeCorla-Souza 1991), the work of Hanson (1992) suggests that the costs could well be higher than reported in the FHWA data. Data collection procedures and definitions should be reviewed to identify means of collecting data on costs that are currently being missed or underreported. This data should be collected as part of the highway social cost accounts recommended in Section V.

IV. ON-GOING RESEARCH

Discussions with a several researchers revealed a number of areas of research activity on the social costs of roadway use. The activities can be broadly classified under the following subjects:

1. Introduction of market mechanisms to transportation. This research is focusing on both the rationale or need for market principles in transportation policy as well as the desirability of various instruments for collecting user fees. Work in this area includes that by Burrington at the Conservation Law Foundation, Newbery, Ketcham, Small, and Hanson.

2. Analysis of the social costs of underinvestment as well as over investment (supra optimal) in highways. Forkenbrock at the University of Iowa is active in this area as is Lee who has made estimates of what portion of the existing highway system does not meet a benefit-cost test.

3. Air pollution social costs. Work -in this area includes the work of Mark DeLuchi at UC-Davis and MacKenzie, Dower, and Chen at the World Resources Institute.

Admitting that there is research on-going that was not or could not be identified, the overall impression of the on-going research is that interest is growing in the subject of social costs and appropriate user fees, but that the work is limited by the funding available. Douglas Lee notes that work in the above areas has been on-going for two decades, but only recently has it become a topic of "polite conversation."

V. RECOMMENDED APPROACH TO QUANTIFY SOCIAL COSTS AND RESEARCH NEEDS

A. Introduction

As noted above, the literature on the social costs of highway use is limited. Few comprehensive treatments exist which attempt to include all social costs. Research on specific areas of social costs are also uneven, with some areas such as the costs of highway crashes being well treated (albeit without distinction between societal costs and social costs) and others, such as the costs of water pollution, quite limited.

It is implied in the FHWA statement of work that the key underlying rationale for research in the area of social costs of highway use is movement towards establishing urban highway tolls. This underlying goal implies a research program that would build knowledge that would assist in the design and establishment of such tolls.

Based on the review of existing literature, four areas of research would serve such a research program:

1. Studies on aggregate social costs at urban and national levels, with supporting research in three specific areas where important gaps exist, namely water pollution; the social costs of crashes, including unprotected users; and differences in per capita travel within urban areas.

2. Development and implementation of a set of social cost accounts linked to conventional transportation data and accounting systems.

3. Research support for publicly and privately funded transportation demand management actions and infrastructure projects where highway pricing or other traffic demand aspects are important parts of the project. The research support program would also evaluate social costs of specific highway segments or other transportation infrastructure where these costs are unusual in type or magnitude.

4. Evaluation of the application of integrated least-cost planning (developed and now extensively used in the electric and gas utility industries) to transportation planning.

In addition to these four research areas, it is recommended that a Center for Research on Least-Cost Transportation Planning be established. Such a center would both undertake and fund research in areas including highway social costs, highway user charges, and transportation demand management. The

Center could be a new, stand alone entity or could be established by assigning an additional discrete focus to one of the centers in the University Transportation Center's Program.

This recommended research agenda recognizes certain critical underlying conditions. It is evident from the literature that the social costs of highway use are uncertain, but very large. Some further estimation is useful to fill in important gaps. While sufficient scientific information exists to establish average minimum user charges for urban areas or for states, **perceived** political realities do not permit higher user charges. Such user charges include tolls, fuel taxes, excise taxes or other charges, possibly including IVHS (intelligent vehicle/highway systems) that would account for all existing direct costs in most instances. This ignores the even larger social costs, which would raise highway tolls or other user fees by an even greater amount.

While minimum average costs can be determined at this time, marginal cost pricing is the ultimate goal in establishing efficient highway tolls. More information and data will be required to determine marginal costs and establish user charges at specific times and places. Where congestion costs are dominant, this information can be readily collected and partial marginal cost fees established based on lost time. More work would be required to include marginal energy use and emissions costs.

Within this context, it is prudent to focus some research on urban areas where innovative highway charges could be implemented in the near future. Areas include non-attainment areas under the Clean Air Act and tolls for new highways, tunnels, and bridges under public or private ownership being built to meet congestion relief needs. This market oriented research focuses on issues of consumer acceptance of transportation demand management (TDM) and the social and economic effects of various TDM measures. This in turn will set the groundwork for future program and project designs.
This research agenda also recognizes that the development of social accounts will, over time, provide a basis for monitoring the evolution of social costs and environmental impacts associated with transportation without necessarily expressing those costs in monetary units. Such an accounting system is useful for considering environmental and other social implications of the transportation system, and lays part of the framework for estimating social costs as they become better defined, measured, and understood. As actions are taken to reduce urban emissions, such accounts will provide a baseline against which progress can be measured.

B. A Synopsis of Methods for Valuation of Social Costs of Roadway Use

The literature on the valuation of social costs embraces a number of techniques which represent different methods for placing monetary measures on the social costs of using urban roadways. Figure 2 is a pictorial presentation of these techniques. Assigning a value to social costs is difficult since by definition social costs arise when the existing market for a good or service fails to include the entire spectrum of private and external costs that result from the consumption of the good or service. Roadway use has external effects that are not fully considered by the users of the roadways but which are imposed on other system users or on the non-benefiting public.

The existing approach can broadly be divided into direct and indirect valuation methods. Direct valuation methods rely on unveiling existing; but hidden preferences. Markets are necessary to uncover these preferences, thus direct valuation methods are all market-based. Indirect valuation methods are based on physical linkages such as dose-response relationships. Once a physical link has been established between an action by the roadway user and some measurable cost, a value can be assigned to the action.

As shown in *Figure* 2, direct valuation methods can be divided according to the kind of market that is used to reveal preferences, i.e., surrogate markets and experimental markets. Surrogate market approaches use markets in which goods and services or factors are traded and in which environmental costs are attributes of those goods or factors.

One type of procedure that uses surrogate markets is the hedonic property price method. Hedonic property price models look at the housing market. As a first step, these models try to determine how much of the difference in the value of properties can be attributed to a particular environmental effect. In a second step they then try to infer how much people are willing to pay to avoid the environmental effect, thus assigning a cost to the effect. Another hedonic method, wage-risk studies, tries to determine a monetary measure for the probability of death or injury by looking at the wage differential among high-risk jobs and low-risk jobs.

Hedonic methods are subject to a number of problems. First, all variables that may affect the value of the property or the wage must be included in the analysis in order to guarantee unbiased estimates, i.e. estimates that on average asses the correct values to environmental effects. The variables of interest, however, are often closely correlated so that it is difficult to single out causal effects. Moreover, the variables are often hard to measure. Second, from a theoretical point of view, the analysis is very sensitive to the functional form of the models chosen. Third, it is assumed that people are able to choose the most preferred bundle of attributes given their budgetary constraints, which is usually not the case because not all possible combinations of attributes are available to choose from.

Travel cost studies estimate the cost of transportation in terms of money and time that people actually spend for transportation. Assigning value to time based on foregone earnings gives a measure of the social costs of, say congestion. The travel cost method faces basically the same problems as the wage-risk approach or the property price approach. In addition, it raises the question of how to assign a monetary value to time. The most commonly used measure is a person's wage rate. Since large groups within the population do not earn wages, this measure usually undervalues time. On the other hand, using wages to measure the value of time implicitly assumes that the time spent on the congested road would otherwise have been spent working. Since most working people do not have a free choice over the number of hours they work, it is often more likely that the traveling time is taken out of leisure time. Moreover, people may derive some satisfaction from driving so that foregone earnings may overstate the costs.

A second way of revealing preferences is through experimental markets. Contingent valuation methods use surveys or laboratory experiments to create markets. Respondents indicate the amount they would be willing to pay to avoid the stated social costs if a market existed. This method is flawed by a number of biases through the design of the survey, the sampling procedure and/or the interviewing process. Also, creating artificial markets through hypothetical questions lacks the true incentives of a market. No punishment exists for doing the 'wrong' thing, no satisfaction is gained from doing the 'right' thing. However, this method has the advantage that it is applicable in just about any context.

Indirect valuation methods do not try to infer preferences but instead focus on the physical linkage between environmental factors and a market. These linkages, often captured in dose-response functions, measure the damage actually done in terms of health, materials or vegetation and then use 'real', surrogate, or experimental markets to determine the costs in monetary terms. Physical linkage is chosen over preferences when people are thought to be unaware of the effects and hence unaware of their preferences. Measuring the damage actually done is often a difficult task because the physical linkages are uncertain or so complex that it is difficult to measure the cost of a single factor. This is particularly true for broader costs such as climate change or acid rain. There are linkages, however, that are quite well understood. For example, some crop damage has been linked to specific environmental factors, and the effects of lead and of ground-level ozone on urban health have been widely researched and are known with some degree of certainty.

C. Specific Recommendations on Research Needs and Approaches

1. Urban and National Level Social Costs

Some aggregate estimates of urban and national level social costs have been made since the 1982 Federal Highway Cost Allocation Study. These studies include the estimates of DeCorla-Souza and Kane (1991), Hanson (1992), Hart (1985), Kinney (1991), and Ketcham (1991), and most recently Machenzie et. al. (1992). In light of the social costs not included in these studies, some of which have been recently treated (the cost of highway crashes (FHWA 1991), it is recommended that an updated range of national estimates be developed. Such an effort should be augmented by specific work delineating the social cost portion of the societal costs of crashes and by work in water pollution. The work would establish a new benchmark range of estimates of the social costs. The current estimates of costs appear to be in the range of $60 to $660 billion per year. Excluding some costs that arguably should be deleted from the high estimate and including costs explicitly excluded from the lower estimates, the plausible range might be narrowed to $150 to $300 billion per year.

In conjunction with the estimate of national social costs, a set of urban area and rural area costs should be developed to better understand the diversity of costs across areas of the U.S. and within urban areas. Urban area estimates should take into account the highly variable travel patterns in different parts of urban areas. One reason for measuring the difference in per capita travel in different locations is to estimate the costs that residential (and possible industrial and commercial) locations should incur. Locations that demonstrate higher per capita travel levels might be subject to user fees according to the "capacity" that those locations demand. Capacity related fees of this type are common in utilities.

A 1983 study for FHWA (Dane County Regional Planning Commission 1983), for example, revealed that residents living in exurban rural areas of Dane County, Wisconsin traveled twice as much as urban (Madison urban service area) residents. Residents in outlying cities and villages traveled more than urban residents but less than their rural neighbors. Similar findings are reported by Newman, Kenworthy, and Lyons (1988) for Perth and New York City. These findings may imply some revisions in the National Personal Transportation Survey to better understand the role of residential location in influencing travel patterns and social costs.

If new survey work is to be undertaken, an initial pilot survey and analysis of a small cross section of cities will require perhaps two years. The focus of this research should concentrate on the level and location of travel, and estimates of the burden on public infrastructure and social costs. This type of information would be useful for the design of tolls and toll collection systems.

The two other recommended work elements in this area are: 1) the identification of the social cost portion of the societal costs of highway crashes, including non-protected users, following on the work of the Urban Institute (FHWA 1991). (MacKenzie et. al. (1992) have recently attempted to distinguish these categories in the Urban Institute Work; and, 2) an estimate of the water pollution associated with highway use including run-off and wet and dry deposition from exhaust emissions. Since a body of research does exist for air pollution and more research is underway, it is not recommended as a work element.

Referring to Figure 2, this research utilizes existing surrogate market estimates of social costs. Research is required for extracting the social costs of crashes, in estimating water pollution damage, and in estimating patterns in urban travel levels or burdens.

2. Development and Implementation of Highway Social Costs Accounts

There has been increasing attention in the environmental science community to the issue of environmental accounts. Environmental accounts include, but are more expansive than social accounts. The underlying rationale is that there is a need for consistent information on environmental burdens (i.e., emissions, effluents, and resource use) and effects (e.g., health effects, materials damage, and ecosystems impact). Environmental accounts in conjunction with routinely collected transportation system information would provide a more complete picture of the direct consequences of transportation systems investments and use. From an economic perspective, the measured and perceived benefits of choices of transportation system investment, management, and use could be better weighed against the private and social costs.

There are a large number of environmental indicators that could be included in a transportation environmental accounting database. As a matter of consistency, environmental accounts should be collected and published by existing, responsible units within the U.S. Department of Transportation and the Federal Highway Administration. The design of the environmental accounts, however, should be the subject of a research effort that would recommend the contents of such accounts, including specific measures, units, and means for collecting the data.

Initial guidelines for such an accounting framework should rely on existing secondary data sources as much as possible and to give emphasis to aspects in Figure 1 which are known to have large social costs such as urban air pollution, congestion, and highway crashes.

This research element falls largely under indirect valuation branch in Figure 2. While some environmental indicators could be assigned monetary value, many of the indicators in the social accounts would be in non-monetary units such as tons of carbon monoxide, tons of nitrogen oxides, and land area under blacktop.

3. Transportation Demand Management Research Initiative

There has been a nationwide increase in transportation demand management (TDM) projects. Projects include measures in five broad categories:

1. Managing flows on specific segments such as computerized signalization and HOV (high occupancy vehicle) lanes.

2. Altering time of travel such as staggered shifts and flexible hours.

3. Altering modes of travel such as vanpooling, transit of various kinds, bicycling, and walking.

4. Altering parking incentives such as imposing fees or increasing fees, providing equal compensation for transportation support for all employees (e.g., an employee using transit or walking would receive compensation equal to the cost of providing parking for those driving), or preferential locations for HOV parking.

5. Marginal cost road pricing for new or existing roads, bridges, areas, etc.

What is often missing in these TDM projects, which are frequently experimental in nature, is a research design by which more useful knowledge can be gained from the projects. Information, such as responses to specific measures, would be useful in improving the management of the projects as well as for establishing a base of knowledge from which other TDM projects and communities could benefit.

It is recommended that a TDM Research Initiative be established which would include a research fund to which project implementers can apply for carrying out the research design, data collection, and analysis aspects of TDM projects. It is also recommended that a Center for Least-Cost Transportation Planning be established. The purpose of the Center is to conduct research on TDM and other transportation planning functions, to administer the TDM research fund, and to gather information on least-cost transportation research, planning, and management, including the use of tolls and other user fees.

4. Analysis of the Application of Utility Least-Cost Planning to Transportation Planning

The electric and gas utility industry has gone through major changes during the last decade in how it plans and manages its investments and operations. Many of these changes have come about due to the adoption of integrated least-cost planning (also known as integrated resource planning, or simply least-cost planning). An important feature of least-cost planning has been the elevation of demand side measures to equal status with traditional supply side measures. If the marginal cost of a demand side measure (including social costs where they have been measured) is less than the marginal cost of new supply, the demand side measure is preferred. Another important feature of least-cost planning is the emphasis given to the social implications of investment choices, including such issues as employment and air pollution.

Many elements of utility least-cost planning are directly applicable to transportation planning in general, and to the issue of social costs and roadway tolls in particular. A review of the applicability of utility least-cost planning to transportation planning is recommended. A brief bibliography of the integrated least-cost planning literature is included in **Appendix B**. An important benefit of the application of least-cost planning to transportation is the potential for placing the issues of highway social costs and highway tolls in a broader economic and planning framework. Such a framework would have an urban wide or regional focus (similar to a utility service area) rather than a static, segment by segment focus.

A review of the applicability of utility least-cost planning to the field of transportation planning would specifically address such questions as the institutional differences in ownership and regulatory authority, the greater difficulty in measuring and metering use of highways, and the large federal funding role. Energy utilities, whether privately or publicly owned, derive their revenue from their service territory, and in the case of investor owned utilities, are subject to state level regulation. Despite these differences, an analysis of the application of utility least-cost planning to transportation is timely.

5. Alternative Research Agendas Not Recommended at this Time

Consideration was given to undertaking direct valuation studies of all externality categories in Figure 1. In addition, publicly funded infrastructure costs at all local levels of government would benefit from a consistent nationwide treatment. While such research would undoubtedly provide interesting new findings and likely revisions of existing social cost estimates, the basic message of large social costs and transfers are not likely to change. Thus, this research is not recommended within a limited funding situation.

Another research area which was not recommended was the use of contingent valuation for estimating the magnitude of social costs. There has been considerable work in this area recently, such as estimates of air pollution damage to visibility in the Grand Canyon. However, work in contingent valuation is subject to a number of difficulties of interpretation. Despite these difficulties, research on contingent valuation is likely to proceed in any event and can be drawn upon as it emerges.

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APPENDIX B – INTEGRATED LEAST-COST PLANNING BIBLIOGRAPHY

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REGION-WIDE TOLL PRICING: IMPACTS ON URBAN MOBILITY, ENVIRONMENT AND TRANSPORTATION FINANCING

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ABSTRACT

Highway tolls are gaining new respectability for two basic reasons: (1) they can be used as a pricing mechanism to moderate highway demand and thereby reduce congestion and enhance air quality; and (2) they appear to be a politically more acceptable way to pay for new public and private transportation investments. At the same time, previous barriers to wider use of highway tolls are breaking down: (1) electronic toll collection systems are reducing - toll collection costs as, well as delays associated with stopping to pay tolls at manual toll booths; and (2) new Federal legislation -- the lntermodal Surface Transportation Efficiency Act (ISTEA) -- provides new inducements to states to consider toll financing and congestion pricing. In this paper we demonstrate, through a hypothetical case study, the type of information planners will need to develop to "sell" a region-wide congestion pricing strategy to decision-makers. Our analysis demonstrates that such a strategy holds great potential to improve urban mobility during peak periods, reduce air pollution, and provide a reliable source of funding for new transportation investment .and service needs as urban areas grow. The benefits of, such a strategy far exceed the public costs for toll collection and supporting public services. Widespread use of new electronic toll collection technology will result in collection costs that are relatively low compared with revenues generated.

INTRODUCTION

Highway tolls are gaining new respectability for two basic reasons: (1) they can be used as a pricing mechanism to moderate highway demand and thereby reduce congestion and enhance air quality; and (2) they appear to be a politically more acceptable way to pay for new public and private transportation

investments at a time when State legislatures are finding it difficult to increase fuel taxes, the traditional means for transportation financing.
At the same time, previous barriers to wider use of highway tolls are breaking down: (1) electronic toll collection systems are reducing toll collection costs as well as delays associated with stopping to pay tolls at manual toll booths; and (2) new Federal legislation -- the Intermodal Surface Transportation Efficiency Act'(ISTEA) -- eliminates previous restrictions on toll financing for federally funded projects. The Act allows federal funding on both public as well as private toll highway projects, and provides new inducements to states to consider toll financing and congestion pricing. In addition, toll authorities would no longer need to remove tolls when bonds are paid off.- Toll facilities can now be major sources of revenue for system-wide investment.

ISTEA allows federal funding for 4R work on existing toll facilities (80% federal match), new non-Interstate toll facilities (50% federal match), and conversions of existing free non-interstate roads to toll roads (50% federal match). For new non-Interstate toll bridges, or replacement, reconstruction and conversion of existing free bridges (both Interstate and non-Interstate) to toll bridges, the Federal share can be 80%. Additionally, ISTEA provides 80% federal match for five congestion pricing pilot projects, three of which can include toll pricing of Interstate highway facilities.

The technology for electronic toll collection continues to improve, and costs can be expected to fall with more widespread use. Such systems are currently fully operational on toll facilities, in Dallas, New Orleans, Denver, San Diego, Oklahoma, Florida and Michigan. They are planned for implementation in the New York Metropolitan area, elsewhere in New York state, New Jersey, Pennsylvania, the New England states, California, Virginia, Illinois, and Georgia. In Europe--Norway, Sweden, France, Italy, the U.K., and the Netherlands systems are either fully operational or planned for implementation soon.

There are two basic methods for electronic toll collection (1). The first uses automatic vehicle identification (AVI) technology. An AVI tag is a read-only transponder that communicates its encrypted identification code via high frequency radio waves to a roadside reader which sends it to a central computer for charging. A second option uses "smartcard" technology. A smartcard is a removable credit card-sized electronic purse with stored value (similar to subway farecards) which can be periodically replenished when the balance is low. It has both read and write capabilities for the purpose of deducting charges instantaneously on board the vehicle.

These new developments are beginning to influence the context in which transportation decisions are made. In the 1990s, policy makers in metropolitan areas in the U.S. will be more willing to consider more widespread use of tolls as a means to address the dual problems of congestion and transportation financing if planners can clearly show them the potential of toll pricing to solve both problems while at the same time providing environmental benefits.

In this paper, we demonstrate, through a hypothetical case study, the general magnitude of the benefits of a region-wide toll pricing strategy with respect to urban mobility, air quality, and transportation funding availability. The analysis demonstrates the type of information planners will need to. develop to "sell" this strategy to decision-makers. We conclude with some thoughts on how toll pricing may be phased in within metropolitan areas in the current federal legislative environment.

CASE STUDY SCENARIO

Our hypothetical case study urban area has a population of about 1.5 million and is heavily congested with traffic volume-to-capacity (V/C) ratios on its arterial, system averaging 0.95 during peak periods. A total of 1 million commute trips occur during the morning and afternoon peak periods. Local transportation policy-makers are under pressure to solve existing congestion problems as well as to make investments to cater to future population growth. The primary modes for commuters are single-occupant vehicles (SOVs), two-person carpools (HOV-2), and bus transit. No high-occupancy vehicle (HOV) lanes exist.

Policy-makers are considering various travel demand management (TDM) options such as increasing carpool and transit use through investments in HOV lanes and improved bus service, along with trip reduction ordinances (TROS) aimed at large employers which would require them to increase their average vehicle ratio (AVR) i.e. the ratio of employee trips to vehicle trips. For comparison with such options, planners have been requested to produce estimates of the costs, and financial impacts of an alternative region-wide road pricing strategy.:

The region-wide pricing strategy will involve establishment of "charging points" for electronic toll collection at strategic locations, mainly on the urban area's principal arterial system, i.e. freeways, expressways, and other principal arterials. Tolls would be charged during peak periods, with gradual reduction of tolls during the shoulders of peak periods. No tolls would be charged during off-peak periods.

HOVs and transit vehicles would not be charged tolls at any time, in order to provide economic incentives for ridesharing. No other public incentives would be provided, except for added public ride-matching services and increasing the frequency of bus service where warranted to serve increases in transit demand.

The peak period toll for SOVs would vary by location based on the need to moderate travel demand. Toll rates would be stepped during the shoulders of the peak to roughly correspond with the shape of the demand curve. Averaged over the entire urban network, including minor arterials, collectors and local streets, the tolls would amount to 12.6 cents per SOV VMT, or 1.5 times the average auto operating cost of 8.4 cents per VMT (2). The toll is roughly equivalent to tripling the price of gasoline for peak period SOV travel only. The average charge is a conservative estimate based on highway marginal costs previously estimated by the authors (16) which showed. that long run marginal costs for new highway capacity in three fast growing urban areas range from 12.5 cents to 19.8 cents per peak period VMT, while short run marginal costs due to congestion delay are 27 to 54 cents per VMT on urban freeways when volumes exceed service volumes for level of service 'D'. In recent California studies, congestion tolls averaging 10 and 15 cents per VMT have been proposed (3,4). The average toll rate of 12.6 cents per solo-driver VMT translates to. an average toll charge for solo-drivers of about 18 cents per mile if only applied on the principal arterial system, since about two-thirds of VMT in large urban areas is served on the principal arterial system (8)

In the next three sections, we provide some order of magnitude estimates of the impacts of this pricing scenario which would be of interest to policy makers. We focus on:

- mobility impacts in the near term
- costs, benefits, and net revenues
- air quality impacts
- long-term implications for financing future transportation investment needs

The estimates we provide are based on macro-level sketch planning analysis using transportation supply and demand parameters which are typical of urban areas in the U.S. with populations above 1 million. More detailed network-based modeling approaches with data for specific urban areas may be used to get finer-tuned estimates. However, we do not anticipate such analyses would result in major deviations from our estimates.

URBAN MOBILITY

What will the impact of the toll pricing strategy be with respect to commute times during the peak periods? To answer this question, we must estimate the impact of the strategy on vehicular travel demand and V/C ratios in the peak periods.

The travel demand effects of applying a region-wide toll pricing strategy will depend primarily on the level of toll charges and the availability of alternative modes. The literature provides a wide range of estimates of the responsiveness, or elasticity, of auto travel demand to auto travel costs and travel times. For example, the price elasticity of an auto commute trip to downtown Boston has been estimated to range from -0.32 to -2.0 , while the travel time elasticity has been estimated to range from-0.62 to -1.85 (20). We chose to derive the effect of region-wide tolls on commute mode shares from recent work by Shoup and Willson (5) on the sensitivity of mode choice to varying parking price levels. When parking price is $5.00 (which equates to a cost per commuter of $2.50 for an HOV-2 i.e. a two-person carpool), SOV use drops by about 24% relative to SOV use when parking is free. We can attribute a similar drop in SOV use with our pricing strategy, because the strategy will result in a similar $2.50 differential between SOV and HOV-2 (assuming a 20 mile round trip at an average toll of 12.6 cents per mile). The additional differential due to HOV-2 savings in auto operation costs and HOV-2 parking cost savings (where commuters have to pay for parking) is conservatively estimated to result in an additional 6% drop in SOV use for a total reduction of 30%.

It should be noted that this estimate of SOV demand responsiveness is based solely on the price differential between the SOV and HOV modes. The average SOV toll charge needed to get a 30% reduction in SOV use could be higher or lower depending primarily on the availability, quality and price incentives on all alternative modes, including bus, vanpool, bicycle and walking. The SOV percent reduction could be increased by providing incentives for carpooling such as priority treatments or subsidized parking for carpoolers, or by providing incentives for transit use such as- express service or reduced fares.

To simplify the analysis, we have assumed that all SOV commuters who shift modes will shift to two-person carpools (HOV-2). Table 1 shows the resulting changes in commute mode shares and VMT per commuter. The mode shifts result in a change in work trip auto-occupancy from 1.10 to 1.27. The strategy results in a 10.5% drop in commute VMT from a base of 8.83 VMT per commuter to 7.90 VMT per commuter.

Table 1: Commute VMT and Travel Time Impacts Per Commute Person Trip

Base Pricing		
Share of travel (1%):		
SOV	77.7	54.4
HOV-2	17.3	40.6
Bus	5.0	5.0
Total	100.0	100.0
VMT/commuter:		
SOV	10.0	10.0
HOV-2	6 0	6.0
Bus	0.5	0.5
Average	8.83	7.9
Travel time/trip (min.)		
SOV	29.5	74.0
HOV-2	37.5	32.0
Bus	49.5	44.0
Weighted average	31.9	28.3

What will be the effect of the toll pricing strategy on non-work trips? The share of non-work VMT in peak periods has been increasing and non-work trips currently comprise roughly 40% of the total VMT in the A.M. and P.M. peak periods, although they comprise more than half the trips. This is because work trips are generally longer than non-work trips. For example, non-work trips comprised about 19% of VMT in the A.M. peak (6-9 a.m.) and about 54% of VMT in the P.M. peak in the Chicago metropolitan area, based on 1990 National Personal Transportation Survey data (21). Non-commuters have fewer carpooling opportunities. However, they have a greater ability to shift their time of travel to the shoulders of the peak or to off-peak periods to save on tolls. We therefore estimate that the effect of tolls on non-commute travel demand in the peak periods would be similar to the effect on commuters, i.e. a drop of about 10.5% in non-commuter VMT.

It should be noted that since non-work daily VMT is not reduced but merely shifted to other times of the day, daily VMT will not change significantly. The 10.5% reduction in commuter VMT equates to only about 2.5% of daily VMT assuming a 60% commute VMT share in peak periods and a peak period share of daily VMT of about 40% (22). Similar impacts i.e. 2% and 5% daily VMT reductions have been estimated for congestion tolls averaging 1 0 and 1 5 cents per VMT respectively based on very detailed modeling techniques (3,4). (Tolls for our pricing scheme average 12.6 cents per VMT).

Table 1 also shows the effects of the pricing strategy on peak period commute travel times. With a 10.5% reduction in peak period travel demand, the average V/C ratio drops from 0.95 to 0.85. This results in significant savings in travel times on the highway system, with average speeds increasing from about 20 mph to about 25 mph. The speed estimates are based on the Highway Capacity Manual (6) for freeway travel, and on previous FHWA work (7) for urban street travel, with appropriate shares of travel on various highway classes (8).

Table 1 indicates that SOV commuters who do not switch to carpools will save about 5.5 minutes per one-way commute trip, at a cost to them of about $1.26 (i.e. 12.6 cents per VMT x 10 miles). This indicates that those SOV commuters who value their time at a minimum of 23 cents per minute or $13.80 per hour (i.e. high income commuters) will be happy with the trade-off between tolls and time savings.. This ignores any value placed on reduced frustration from congestion. Middle and low income SOV commuters could be dissatisfied, especially if carpooling is difficult or not possible for them and they do not place much value on reduced frustration.

Table 1 also indicates that those previous SOV commuters who are forced to switch to carpools will have an increase in commute time of about 2.5 minutes i.e. their commute time will increase from 29.5 minutes (the SOV travel time under base conditions) to 32.0 minutes by HOV-2- under pricing. Their savings in auto operation costs will be about 34 cents (i.e. 4 VMT saved X 8.4 cents per mile). Ignoring any inconvenience costs of carpooling, this means that if they value their time at more than 14 cents a minute or $8.40 per hour, they would be dissatisfied with the trade-off, unless they have additional savings from reduced parking costs. For the group of. current SOV users who value their time between $8.40 and $13.80 per hour, SOV use with the pricing strategy will be too expensive while carpooling will make them worse off.

However, as Table 1 indicates, average commute times are lower than the base condition by 3.6 minutes,- and urban, mobility can be considered to have improved based on this important measure of mobility.

The perception of mobility to the traveler includes some measure of the monetary price paid (e.g. tolls, fares, parking price and vehicle operation cost). We can derive a composite measure of mobility by combining the price paid for use of each mode with the value of the travel time expended in making the trip by that mode. Value of travel time will of course vary based on the income of the trip-maker. For our purposes, however, we assumed a uniform value of $6.00 per hour based on 1985 Orange County, California data (10) adjusted for 1990 and the average U.S. urban area. Table 2 presents the impacts of the pricing strategy on this composite measure of mobility. Auto operating costs were estimated at 8.4 cents per VMT, fares were assumed to be $1.00 per trip and parking was assumed to be free for all commuters. (In the U.S., 95% of employees get free parking at the work site.) Based on these assumptions, the user-perceived cost of mobility increases by about 6 percent on average for peak period commuters i.e. there is a small loss in peak period mobility region-wide,-on average. However, mobility by HOV-2 and bus improves by about 13% and 9% respectively, whereas there is a relatively large decrease of about 19% in SOV mobility.

Table 2: User-Perceived Cost Impacts of Region-wide Pricing Per -Commute Person Trip

Base Pricing		
Toll charges, fares and veh. operation cost,($ per trial):		
SOV	0.84	2.10
HOV-2	0.50	0.50
Bus	1.00	1.00
Travel time value/commute trig ($):		
SOV	2.95	2.40
HOV-2	3.75	3.20
Bus	4.95	4.40
Total cost/commuter ($):		
SOV	3.79	4.50
HOV-2	4.25	3.70
Bus	5.95	5.40
Weighted average	3.98	4.22 (+ 6%)

COSTS, REVENUES AND BENEFITS

While the user-perceived costs of mobility appear to be larger on average under the pricing scenario (Table 2), this is not true when total costs for providing mobility are considered. Total costs for providing commuter mobility include not just the costs privately borne and perceived by-the commuter. Total costs comprise all private costs (for example, employer subsidies for commuter parking and user-borne vehicle ownership costs would be included); all public costs (for example, publicly borne costs for roads, fire and police and subsidies for transit would be included); and all external or social costs (for example-, air and water pollution and noise). Costs for traffic accidents are partly borne privately, partly publicly and partly socially. They include out-of-pocket costs for property damage, medical costs, emergency services, travel delay, legal and administrative costs, as well as losses in wages and household production, and pain, suffering and lost quality of life.

Table 3 presents a comparison of major categories of total costs under the base and pricing scenarios. The first section of Table 3 shows major privately and publicly borne monetary costs except accident costs. They include costs for vehicle operation, parking, ride-matching, bus service and toll collection,, but exclude costs for vehicle ownership and miscellaneous public services. Vehicle operation costs are estimated at 8.4 cents per mile (2), and parking costs at $3.80 per day based on surface lot parking costs (9). The estimates of costs include public costs for providing bus service at 26 cents per passenger mile served during peak periods based on 1985 cost data (15) adjusted for inflation. (Any reduction in public transit service costs resulting from improvements in service productivity due to reduction in traffic congestion under the pricing strategy was ignored).

Also included in the first section of Table 3 are public costs for toll collection and rideshare matching under the pricing alternative. We estimated toll collection costs at $23 per year based on data (1) from the Randstad, Netherlands, where electronic toll collection with smartcards is planned for implementation on a region-wide basis. This amounts to about 10 cents per vehicle per day, which we have used in our toll collection cost estimates. Public ridesharing program costs for serving new carpoolers is estimated at $50 per new carpooler per year, or about 20 cents per new carpooler per day.

Travel time costs have been estimated in the second section of Table 3 using the travel time value of $6.00 per hour. The next section of the table combines the costs estimated in the previous two sections into a "composite" cost. It is interesting to note in the-composite cost section that HOV-2 is the least costly mode from a societal standpoint if accident costs and other costs are excluded, while SOV and bus commute costs are not much different.

Accident costs have been listed next in Table 3. Costs have been estimated at 12 cents per VMT based on-a recent FHWA study (23). The previously listed costs have then been aggregated into a "major costs total" which indicates that the aggregate costs for providing peak period commuter mobility are 8% lower under the pricing alternative. It should be noted that the major costs total does not include many public costs (roadway, fire, police, etc.), private costs (e.g. vehicle ownership) and externalities (air and water pollution, noise,, etc.).Neither are qualitative-costs included, e.g. stress caused by traffic congestion, inconvenience and loss of flexibility due to a switch to carpooling, etc. It is probable that if all of these costs were included in a comprehensive total, the total costs for providing commuter mobility could be shown to be even lower with the pricing strategy.

Table 3: Total Cost Impacts of Region-Wide Pricing
Costs per Commute Trip (dollars)

Base Pricing			
Monetary costs" (except accident costs):			
SOV	4.64	4.74	
HOV-2	2.40	2.60	(new carpoolers)
		2.40	(previous carpoolers)
Bus	2.60	2.60	
Travel time costs:			
SOV	2.95	2.40	
HOV-2	3.75	3.20	
Bus	4.95	4.40	

Composite costs:			
SOV	7.59	7.14	
HOV-2	6.15	5.80	(new carpoolers)
		5.60	(previous carpoolers)
Bus	7.55	7.00	
Weighted average	7.09	6.54	
Accident costs	1.06	0.95	
Major costs total	8.15	7.49 (-8%)	

Includes toll collection, "ride-matching, bus service and private vehicle operation and parking cost (per trip)

Table 4 presents public costs for peak period commuters, toll revenues, and the resulting public cost/revenue ratio. Costs and revenues for non-commuters are not included. Based on the analysis, a public cost/revenue ratio of 0.11 is estimated. In Trondheim, Norway, a cost/revenue ratio-of 0.05 has been achieved with AVI technology (19).

Table 4: Daily Costs, Benefits and Revenues From Peak Period Pricing

Costs	Toll Collection	$54,400
	Ridesharing Program	$23,300
	Total public costs	$77,700
Revenues		$685,280
Cost/Revenue Ratio		0.11
Commuter cost savings:	Vehicle operation	$78,120
	Parking	$221,350
	Travel time	$360,000
	Total	$659,470
Accident cost savings		$110,000
Benefit/Cost ratio	(a) excluding accident cost savings	8.5
	(b) including accident cost savings	9.8

Estimated benefits for peak period commuters are also presented in Table 4. Vehicle operation cost savings are estimated at 8.4 cents per mile (2.), parking cost savings at $3.80 per day based on surface lot parking costs (9) and time savings at $6.00 per hour based on 1985 Orange County, California data (10) adjusted for 1990 and the average U.S. urban area. Accident cost savings are estimated at 12 cents per VMT saved. Excluded are qualitative costs and benefits such as the inconvenience costs of carpooling and any value placed on reduced frustration to drivers, and various other societal costs and benefits. Also, the analysis is limited to peak period commuter traffic, i.e. non commuter costs and benefits and off- -peak costs and benefits are excluded. Based on this limited analysis, daily benefits excluding accident cost savings exceed $650,000, yielding a benefit/cost ratio of 8.5. If accident cost savings are included in benefits, a benefit/cost ratio of 9.8 is achieved.

AIR QUALITY IMPACTS

Figure 1 shows the hydrocarbon emissions for a prototypical 20 mile round trip by a light duty automobile using California's EMFAC7E model (11). The pricing strategy could reduce daily emissions by reducing each of the component sources of emissions:

- Diurnal emissions can be reduced if new carpoolers reduce the number of autos they own.
- Trip-related emissions can be reduced if new carpoolers are picked -up at home rather than at a carpool staging area.
- VMT related emissions will be reduced due to reductions in VMT and increases in speeds at which vehicles travel during the. peak periods.

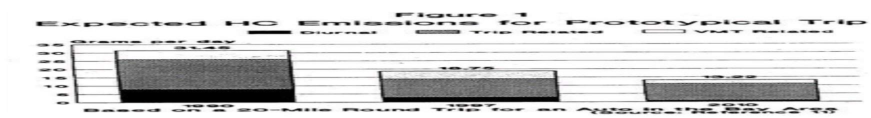

Table 5 provides estimates of the impacts of the pricing strategy on daily hydrocarbon emissions. Diurnal emissions are based on an assumption that 10% of existing and new carpoolers own one less vehicle than they would if they did. not carpool. Trip related emissions are based on the assumption that carpool-staging areas will not be used, i.e. the second person of a two-person carpool will be picked up by the driver at home. The analysis indicates that the pricing strategy will result in a 15% reduction in peak period emissions from commute vehicles. However, since peak period emissions from commute vehicles comprise only about 24% of daily vehicle emissions (assuming a 60% share of peak period VMT and a 40% peak period share of daily VMT), the impact on-daily emissions is relatively small -- about 3.6% reduction in daily emissions. This assumes that there will be no reductions from non-commute VMT (since we have assumed that non-commute VMT eliminated from the peak periods will merely be shifted to other times of the day). However, since ozone concentrations are more sensitive to hydrocarbon emissions in the morning, we can expect an effect on ozone concentrations somewhat greater than that indicated by the 3.6% reduction in daily emissions.

Table 5
Changes in Hydrocarbon Emissions (1990)

Base Pricing		
Diurnal Emissions: No. of vehicles	466,350	454,700
Daily Emissions (gm)	1,865,400	1,818,800
Trip related emissions: No. of trips	863,500	747,000
Daily Emissions (gm)	17,270,000	14,940,000
VMT related emissions: VMT	8,830,000	7,900,000
Average speed (mph)	20	25
Emissions/mile (gm)	0.35	0.26
Daily emissions (gm)	3,090,500	2,054,000
Total emissions (gm)	22,225,900	18,812,800 (15% red.)

Carbon-monoxide (CO) emissions are even more sensitive to changes in speed within the speed range 20-25 mph (12). Also, since mobile source CO emissions generally comprise- a greater share of total CO emissions, the impact of emission reductions on CO concentrations will be greater than for ozone.

TRANSPORTATION FINANCING

We now turn to an evaluation of the impact of the pricing strategy on future ability of the urban area to pay for new transportation investments and services which will be needed to serve its population. We consider two alternative scenarios of travel growth over the next 20 years: 20% and 50%. These magnitudes of gross percentage growth equate to average annual compound growth rates of 0.9% and 2.0% respectively. For comparison, national VMT is anticipated by FHWA to grow at a compound annual growth rate of 2.3%.

In our hypothetical urban area, as in many urban areas in the U.S. which are growing rapidly, finding money to finance new highway and transit infrastructure and services will be difficult. Current fuel-taxes, which average about 30 cents a gallon (including both federal and state taxes), are barely sufficient to maintain and rehabilitate existing highway infrastructure. The prognosis for future financing from fuel taxes is worse, since energy efficient vehicles, alternative fuels, and electric vehicles will erode revenues from fuel taxes. The pricing strategy promises to generate new revenues which can be ploughed back into new transportation investments and services needed to serve growth in travel. Our analysis will focus on the question: Will these revenues be adequate?

To answer this question, Table 6 compares the financing needs under existing base policies and the region-wide pricing strategy. First, new highway capacity investment needs are estimated based on a desire of the urban area to maintain an average V/C of 0 85 (i.e. level of service D) during peak periods. Investment costs are estimated to average 20 cents per peak period VMT for VMT in excess of 11.9 million (i.e. the VMT which can be served at a V/C of 0.85). The unit investment cost is a conservative estimate, since it is based on the assumption that widening is feasible wherever new capacity is needed. The unit costs were derived from widening costs for built-up and outlying areas (1

3), a discount rate of 10%, 20 year service life, and appropriate peak period travel shares and service volumes for various facility classes at a V/C ratio of 0.85 (14).

Ridesharing program costs were estimated at $50 per year per new carpooler induced under the pricing strategy. New transit service costs were estimated at 26 cents per new commute passenger mile served during peak periods based on 1 985 cost data (1 5) adjusted for inflation.

Table 6: Transportation Financing Impacts of Region-wide Peak Period Pricing

Highway Costs	**Base with 20 yr growth**		**Pricing with 20 yr growth**	
	(a) 20%	**(b)50%**	**(a)20%**	**(b)50%**
Peak VMT (millions)	15.9	19.9	14.2	17.8
Excess VMT (millions)	4.0	8.0	2.3	5.9
New hwy. cap. cost (millions/year)	$300	$400	115	$295
Transit/ridesharing costs				
New carpoolers (thousands)	--	--	140	175
New bus passenger miles daily (thousands)	100	250	100	250
Ridesharing program cost (millions/year)	8.8	--	--	7.0
New bus service cost (millions/year)	$6.5	$16.3	$6.5	$16.3
Total Costs and Financing Needs				
Costs (millions/year)	$206.5	$416.3	$128.5	$320.1
Equivalent fuel tax (cents/gallon)	29	47		
Equivalent SOV peak toll rate on principal arterials (cents/VMT)	--	--	9.6	18.9

Financing needs in terms of a fuel tax equivalent under base policies are estimated to range from 29 cents per gallon to 47 cents per gallon, depending on the travel growth rate. The required tax was estimated assuming fuel economy of 20 mpg, daily VMT at 2.5 times peak period VMT, and weekly VMT at 6.8 times daily VMT. To estimate financing needs in terms of required net toll proceeds (i.e. after collection costs are subtracted) under the pricing strategy, it was assume that the SOV share for noncommute VMT would be equal to the SOV share for commute VMT. The estimated equivalent SOV peak toll rate is the average rate over the entire urban highway network, including minor arterials, collectors and local streets, and over the entire peak period, including shoulders. The net toll rate if tolls are only collected on principal arterials was estimated assuming 70% of VMT will be on principal arterials.

The results of the analysis in Table 6 indicate that a surplus of toll revenues will result if the urban area's travel growth over the next 20 years is projected at 20% -- net revenue needs are just 9.6 cents per SOV mile driven on principal arterials, far lower than the gross toll rate of 18 cents proposed under the pricing strategy. On the other hand, if the urban area is projected to grow by 50%, toll revenues will be inadequate, since the net requirement of 18.9 cents per mile exceeds the gross toll rate proposed. This suggests that faster growing areas may need to set higher toll rates. The authors have previously estimated (16) that. capital costs for new highway capacity in the Los Angeles metropolitan area will be as high as 19.8 cents per peak period VMT, based on proposed long range transportation plan cost estimates.. This equates to an average toll on principal arterials of 28 cents per mile.

Surplus toll revenues (under lower travel growth scenarios) can be returned to, highway users through fuel tax rebates, or could be used to pay for any shortfalls in revenue needed for routine highway operation and maintenance costs. Other possible uses are: subsidies to other travel modes or user-side subsidies ('travel vouchers") to low-income highway users adversely affected by the pricing strategy. Experiences in other countries (17,18).have shown that highway users are more willing to accept tolls on existing facilities if they are assured that revenues will be used to improve transportation facilities and services.

CLOSING

This paper has provided some order of magnitude estimates with respect to impacts of a region-wide peak period pricing strategy. Our analysis demonstrates that such a strategy holds great potential to improve urban mobility during peak periods, reduce air pollution, and provide a reliable source of funding for new transportation investment and service needs as urban areas grow. The benefits of such a strategy far exceed the public costs for toll collection and supporting public services. Widespread use of new electronic toll collection technology will result in collection costs that are relatively low compared with revenues generated.

However, there are several political and technical issues which will need to be addressed before a full scale implementation of region-wide pricing becomes feasible. Among the political issues which would affect our hypothetical urban area are:

Equity concerns: How will the impacts on low income SOV users who can't carpool be ameliorated?

Public hostility: How will middle income SOV users, who don't. value their time as highly as high income SOV users, be appeased if they can't carpool?

Inter-jurisdictional questions: Most principal arterials in urban areas are state-owned and most metropolitan areas have multiple local jurisdictions. State and local governments in the area will have to develop the necessary institutional mechanisms to implement a coordinated pricing strategy.

Use of Revenues: Should revenues be limited to highway uses? Can they be used to subsidize other modes and to provide user-side subsidies to low income commuters adversely affected?

Privacy: How will individual privacy, be protected if pre-paid accounts or smartcard technology is not used?

Among the issues of technical concern are:

Technology compatibility: How will users from outside the urban area be charged? Unique systems are being developed on the west coast, in the northeast and in the southwest. For the long run we must move towards uniform protocols and standards.

Enforcement mechanisms: Will video cameras be acceptable to monitor HOV requirements? Can vehicle owners rather than drivers be cited for violations?

Price determination: What methods will be used to set prices at various charging points -- congestion-based charges, or charges based on long-run marginal costs for new capacity? How can pricing systems be simplified to ease customer understanding?

Impact assessment: How will the behavioral and secondary impacts of alternative proposals be evaluated?

A study to be conducted by the Transportation Research Board will begin to address such issues, among others. Meanwhile, attempts must be made to phase in the idea in less threatening ways; for example, by introducing differential charges by time of day on existing toll facilities and on new toll facilities, by introducing charges for non-qualifying vehicles on HOV lanes which are under-utilized, and by introducing peak charges for parking. As highway users get used to the idea that a good level of service during peak periods is something that has to be paid for, wider use of pricing --'by introducing it on existing free facilities which have been improved or are planned for improvement -- can be phased in. As the impacts of these pricing projects become better known and understood, more ambitious region-wide pricing schemes can be attempted.

The inducements in the ISTEA for toll facilities and for congestion pricing demonstrations will provide us with valuable experience with this new tool. Based on these experiences, it is conceivable that future federal legislation will eliminate the prohibition of tolls on currently free Interstates, thus removing a major hurdle to region-wide pricing.

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